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AFTER GENEVA

The International Conference on the Peaceful Uses of Atomic Energy, which ended at Geneva on August 20th, was a notable conference in every way. It was a truly international meeting in fact as well as in name ; representatives of over seventy countries were in attendance and scientists from both East and West showed a common interest in making it a success. It will obviously be months before a true assessment can be made of the value of the information that has been exchanged in the mass of scientific and technical papers released. Few of them probably contained any facts which were not already known or expected by those engaged in such work in this country, but it was amply demonstrated that, despite all security barriers, lines of thought and development have inevitably run parallel in different parts of the world. It has shown clearly that nations have much to gain and little to lose by free discussion on the problems that must still be solved in order to exploit atomic energy for the ultimate benefit of mankind. For example, high on the list of such problems is that of radiation hazards, and it was recognised that international co-operation is essential in the study of the effects of radiation and in the administration of safety standards throughout the world. The scope of the conference was wide, covering not only nuclear physics and reactor technology, but also chemistry, metallurgy, biology, radioactive isotope production and their uses, &c. An examination merely of the titles of the papers tabled reveals the enormous field in which any large-scale development of nuclear energy will inevitably make itself felt. The conference has also provided information on the future availability of uranium and thorium, and the United States of America announced the prices at which it is prepared to sell natural uranium and heavy water, and to lease uranium enriched up to 20 per cent in U235. All this means that a more realistic appreciation of the possible economic lines of development can now be made than has been possible previously. Firm facts are displacing speculation. As Sir John Cockcroft pointed out in one of the closing sessions, it may still be more economic in some countries to develop other sources of power than to embark on a programme of atomic energy development at this present time.

Of dominating interest to the engineer is the question of what types of reactor should be developed and built. Though all factors point to the fast breeder reactor, producing more fissile material than it consumes, as being the ultimate goal for power production, there are differences of opinion as to the types that should be built during the intermediate stages. Though a tremendous amount of detailed research and development work is still required in support of any future programme for nuclear power, it would be fair to say that the engineer considering future projects is already embarrassed by the speed with which research has proceeded in the last few years, research which has demonstrated the possibilities of constructing many types of reactor. It is almost as if in the days of the horse-drawn carriage he had been given a glimpse of every type of modern form of transport and then asked to evaluate the most economical and safest method of travel for the future. Sir Christopher Hinton, the managing director of the Industrial Group of the United Kingdom Atomic Energy Authority, expressed forcibly at Geneva his conviction that designers of atomic power plants should not attempt to be too ambitious in their first designs. Undoubtedly, the immediate need in the next few years is for experience to be gained of actual power production on an industrial scale without undue risk of accident. At present, this country leads the world in this field with the gas-cooled, graphite-moderated, natural uranium reactor of the type being built at Calder Hall. When compared with some of the types of reactor that have recently been discussed—for example, reactors using a liquid metal as a coolant with enriched uranium fuel—the Calder Hall reactor may appear to be large and of low efficiency. But, on the other hand, it is reported to be a reliable system and absolutely safe, and experience in its design and operation will almost certainly bring improvements. It is this type of reactor that will be built by groups of industrial firms for the Central Electricity Authority during the first stage of Britain's nuclear power programme, and, as announced by the Minister of Fuel and Power, Mr. Geoffrey Lloyd on June 13th, a further six are also to be built for the

prime purpose of producing fissile material. It is also clear that this is the type of commercial power reactor that Britain will be able to supply to other countries in the next few years.

Whether or not the advanced state of development of the gas-cooled reactor, its simplicity and safety features, will make it an attractive proposition to other countries is a matter that will be awaited with some interest. In an early paper to the conference, members of the British delegation pointed out that only Britain, the United States, and the Soviet Union were likely to be in a position to provide nuclear power stations for other countries because of the high capital investment required. It is therefore of considerable importance to this country, maintaining its standard of living as it does to a large extent by the scale of its technical skill, that it should secure its share of any future reactor export market. We are, in fact, faced with two aspects of the problem of exploiting nuclear energy; the design and construction of large power stations to meet our own immediate internal requirements for more electrical power than we are going to be able to get from coal, and a study of the needs of other countries. So far the achievements of this country have been remarkable. That we are in such an advanced stage of nuclear power development despite the fact that Harwell and Risley were not established until after the war, is a demonstration to the world that our scientific and technical abilities are still of the highest. But in some ways we are now entering a more difficult period. The field of development has widened and much skill will be needed in the selection of the paths to be pursued; for, not only is the cost of technical development high, but, as has been pointed out on numerous occasions recently, there is a real shortage in Britain of young scientists and engineers. The Geneva conference has been a historic event in the development of the peaceful uses of atomic energy. It so happens that it has taken place at an important time for this country; a time when private industry has recently entered the field, and more of the universities are setting up elementary courses for students. The next decade will be critical, because it is then that nuclear engineering must establish itself and its lines of development be made clear.

THE T.U.C. COUNCIL REPORT

This year's report of the Trades Union Congress General Council issued last Tuesday in readiness for its presentation to the T.U. Congress next month is in one respect a more depressing document than usual. It is unreasonable to expect to find in any document issued by a political party, or in the words of party spokesmen, balanced and non-partisan praise or criticism of the Government in power. For it is a well-appreciated part of the party "game" that all questions should be looked at one-eyed and that there shall be refusal to recognise that any other view can reasonably be held. But though the T.U.C. is closely associated with a particular political party its Council should surely be capable of more adult thinking than that of an insignificant back-bencher. We find it very deplorable, therefore, that it expresses certain of its strictures on the Government in this report in the language of ill-argued prejudice. It finds it gravely disquieting that "the Government has revealed no positive plan to increase industrial development" without apparently recognising what the August *Bulletin for Industry* reveals to be a fact that gross fixed investment in industry has gone on merrily increasing ever since 1948, plan or no plan. It is equally disquieted that the Government "has allowed increases in profits . . . and dividends . . . to outstrip increases in wages" without, seemingly, taking into account the facts that increases in dividends and interest were held in check after the war far longer than were increases in wage rates and that increases in real capital, whatever the nominal capital involved, certainly justify greater returns. It claims that "the Government has turned its back on fair shares" and in recent Budgets has "put the interests of persons with large incomes" before the needs of the nation, a claim that seems to suggest that when taxation is raised the rich should be soaked, but when it is reduced the workers alone should receive appreciable benefits! As for a remark about the concern of the Council "that the Government is not doing all it can to enable British industry to meet on the best possible terms the increasingly fierce competition in the export markets," it can only prompt the angry reply that annual demands for increased wages, unjustified by improved productivity, are the opposite of helpful. A table in the *Bulletin for Industry* reveals that over the whole economy wages and salaries, per unit of output, are continuing to rise with the necessary consequence that prices are being forced up, goods are being diverted from exports to meet the pressure of home demand, and imports are being encouraged to rise, thus contributing to the country's economic difficulties. The Council would do better to stress to the Congress the need to increase the size of the national "cake" than to utter unreasoned and envious views about how the "cake" should be cut!

But if the expressed views of the Council on economic affairs thus call for criticism—we notice that even so restrained a contemporary as *The Times* has been pricked into astringency!—there is fortunately a great deal else in the report that is much more sane, sensible and balanced. In particular, the report summarises the part played by the Council in endeavouring to bring to an end the dock strike and the railway strike. Unquestionably, in those affairs, the Council acted with a full sense of its national responsibilities, recognising that the strikes were doing serious damage to the country's economy. It had it in mind, too, that the continued prosperity, besides the immediate employment, of many union members outside the industries directly concerned was being threatened. It also recognised, no doubt, that because there entered into both these disputes elements of inter-union jealousy the prestige of the whole trades union movement was being threatened. Had the Council taken no effective action it is by no means impossible that the Government, supported by public opinion, would have been stung into an attempt to prevent future similar strikes by legislative action. In fact, such legislative action, though suggested, was rejected because the Government and other influential bodies agreed with the Council that such legal restrictions upon the right to strike would create greater difficulties and provoke rather than avoid trouble in industry. It was, however, clearly felt at the time that, wisely though the Council was acting and beneficial though its intervention was proving to be in helping to bring the strikes to an end, it could have acted more effectively if it had been able to intervene at an earlier stage. There, however, the actions of the Council were restrained by the Rules and Standing Orders of the Congress, one of which prevents it disseminating information about a dispute outside the industry concerned, and another of which prevents it from taking any initiative until negotiations have actually broken down and deadlock has already been reached. We are glad to see, therefore, that the Council is to propose to Congress amendments to those Rules so that it will be able to exercise its proved conciliatory powers more effectively and at an earlier stage. It may, we hope, be confidently expected that Congress will approve the amendments.

Centenarians

In an article entitled "Centenarians," in our issue of August 12th, we mentioned that a special Centenary Number would be issued to mark the event of the Centenary of this journal on January 4th next year. We would like to include in that Number a list of British manufacturing or consulting firms, institutions and societies, and journals, operating in the engineering, iron and steel, shipbuilding and other fields with which this journal is associated, that will have celebrated their Centenaries by January 4, 1956. Will each such firm, institution or journal please inform us about the date of its foundation, its title at that time and its present title? The information should be sent to The Editor, THE ENGINEER, 28, Essex Street, London, W.C.2, not later than September 5th next.

A Seven Day Journal

Conference on Steel Works Cranes

A CONFERENCE on steel works cranes, which is being arranged by the plant engineering division of the British Iron and Steel Research Association, is to be held at the Hotel Majestic, Harrogate, on October 5th and 6th. Mr. W. F. Cartwright, assistant managing director of the Steel Company of Wales, Ltd., will preside at the various sessions of the conference. The papers which are to be presented will deal with steel works requirements for cranes; structural design; mechanical factors, such as bearings, couplings, rail wheels, &c.; crane cab layout and design of controllers; electrical equipment, and safety aspects of crane design, operation and maintenance. Much of the discussion at the conference will be specifically related to the electric overhead travelling crane, but other aspects of the subject will also be considered. It may be recalled that a specification for heavy duty electric overhead travelling cranes for use in iron and steel works was first issued by B.I.S.R.A. in May, 1950. A revised edition of that specification has been recently prepared in which an attempt has been made to reduce the weight and cost of the crane. For the past four years or so B.I.S.R.A. has been testing cranes used in steel works to find out how far the weight of crane structures can safely be reduced and how structural defects can be prevented under continuous and heavy duty. The nine cranes so far studied range from a small 4-ton ingot stripper to a 250-ton forging crane, and represent all the principal kinds used in the steel industry. Tests have been made during normal use to determine loadings in the varied operations performed in a steel works. Abnormal loadings have been specially studied. B.I.S.R.A. says that although the investigations have shown that the structures of most kinds of cranes are broadly satisfactory, the low stresses recorded in some of the tests indicate that designers have not taken full advantage of the maximum permissible stresses, but have made overgenerous allowance for the severe conditions in steel works. It is considered that the information now available on impact and fatigue conditions should make it possible to design lighter and more efficient cranes.

Snaefell Mountain Railway

A BOOKLET has been published by the Light Railway Transport League to mark the sixtieth anniversary of the Snaefell Mountain Railway, which was opened on Wednesday, August 21, 1895. It was the first and still is the only electrically worked mountain railway in Britain. In an interesting history of the railway Mr. F. K. Pearson points out that a survey with a view to constructing a railway up the mountain was made by Mr. G. Noble Fell in 1887–88, and the project was taken up in earnest in 1893 when the Douglas and Laxey Coast Electric Tramway, as it then was, was opened to traffic as far as Laxey. It was decided to adopt electric traction and use the Fell centre rail system for guiding and braking, with a 3ft 6in rail gauge. The railway starts on the hillside above Laxey and its upper terminus is situated 44ft below the mountain summit, some 1990ft above sea level. Except for the termini and two short intermediate portions, the entire line was made on a gradient of 85 per cent, the remainder being at 1 in 15 and 1 in 42½. The actual Fell system for mountain railways incorporated a double-headed rail between the running rails to give additional traction and braking effort. Developments which had been made in electric passenger car design when the Snaefell railway was built made the equipment available quite suitable for ascending the 1 in 12 gradient by ordinary adhesion. For this reason the Fell rail was adopted only as a safety device against derailment and not for any actual drive. Each bogie of the cars was fitted at the inner end with a pair of horizontal flanged wheels, which registered on the Fell rail to provide a guide, and special clasp brakes were fitted to grip the rail and provide a supplementary braking effect during downhill journeys. It is of interest to note that the six original bogie passenger cars built for the railway are still in service, substantially unaltered and containing much of the original electrical equipment supplied in 1895 by the Salford Ironworks (Mather and Platt, Ltd.). It is estimated that during the past sixty years the railway has carried more than 2,500,000 passengers. The commemorative booklet on this interesting railway can be obtained from the offices of the Light Railway Transport League, 245, Cricklewood Broadway, London, N.W.2, price one shilling.

Waterloo and City Railway Modernisation

THREE escalators are to be provided at the Bank Station on the Waterloo and City Railway to take the place of the long tunnel formed of an inclined pathway which is interspersed with short flights of three or four steps at frequent intervals. This tunnel is used most during the morning and evening rush hours, and it has been stated that at the heaviest hour it is used by about 10,000 people as compared with some 6000 in 1939. Before the war the former Southern Railway as a long term policy provided, for this railway, new rolling stock, improved signalling and other amenities. It was the intention then to drive new tunnels in order to install three reversible escalators with lengthened platforms to reduce walking distance, but this scheme was prevented by the outbreak of war. This week, it has been stated that as part of the modernisation plan for British Railways the Southern Area Board of the British Transport Commission now intends to implement the proposals for providing escalators at the Bank Station and Messrs. Mott, Hay and Anderson are pressing ahead with the development of the scheme. The work will be put in hand immediately the plans are completed, but the magnitude of the work—it will cost over £750,000—and the availability of materials and machinery will probably mean that the inevitable interval before the escalators can be working may be three years.

Report of H.M. Principal Electrical Inspector of Mines

THE report of H.M. Principal Electrical Inspector of Mines for the year 1952 has been published by Her Majesty's Stationery Office for the Ministry of Fuel and Power. In the year under review inspectors made 607 inspections on the surface and 627 underground, while forty-four inspections were made at metalliferous mines and 664 at quarries. The report repeats previous warnings regarding unauthorised alterations to intrinsically safe apparatus and circuits. It also mentions that interference with certified flameproof and other intrinsically safe apparatus is dangerous and will invalidate the Ministry's certificate. A table gives the number and horsepower of motors in use for various duties on the surface and underground. There are brief statements concerning fatal and non-fatal accidents which numbered seven and sixty-five, respectively. One tabular statement gives the analysis of electrical accidents and dangerous occurrences by divisions, and another gives the classification of all accidents due directly or indirectly to the use of electricity for the years 1943 to 1952, while a companion table records the number of killed and injured. Table V lists the accidents involving trailing cables and plugs; and accidents from electric shock or arc burns due to defects in trailing cables are recorded in Table VI. Detailed descriptions and analysis of cause and effect are given of the fatal accidents, and accounts are included of some of the non-fatal accidents, together with photographs and diagrams. At the end of the report particular reference is made to the dangers of using open-type air-cooled resistors in particular positions, and of old-type remote control circuits. Suggestions are put forward for the suspension of wire-armoured cables in roadways, and attention is again drawn to the danger of detonators being ignited by bare detonator wires making contact with a source of current.

Car Assembly Plant

THE factory of Briggs Motor Bodies at Balby, near Doncaster, has now been extended to include the assembly line for the Ford "Popular" motor-car. The last of these cars to be built at Dagenham was completed on July 21st, and during the annual two-week shut-down the plant was transferred to the Briggs works at Balby. Production was resumed on August 8th and will continue at 100 to 120 cars a day. At a ceremony in Doncaster last week, Lord Airedale, a director of the Ford Motor Company, Ltd., said that this development formed part of the company's £60,000,000 expansion programme, and pointed out that the new production line would enable the company to increase Great Britain's vital exports. He continued by observing that he had over fifty years' acquaintance with the Great North Road, curiously so-called, and could find no improvement, other than of surface, between Yorkshire and Baldock: there were still many miles where overtaking was impossible in the presence of oncoming traffic. He drew attention to the fact that for several miles north of Alconbury land had been cleared, culverts constructed, and all preparations made for a second carriageway, and condemned the absence of any attempt to complete this. The new plant is supplied with assembled chassis, engines, transmission, running gear and electrics, and manufactures the bodies, trimming and upholstery. The fact that the body is made in the building housing the assembly line enables the sequence of assembly to be determined strictly by functional considerations.

Index to THE ENGINEER

THE Index to THE ENGINEER, Volume 199, January to June, 1955, is now ready and has been posted to all readers who have previously applied for copies. A copy will be sent free of charge to subscribers and regular readers of THE ENGINEER on application to the Manager, THE ENGINEER, 28, Essex Street, London, W.C.2.

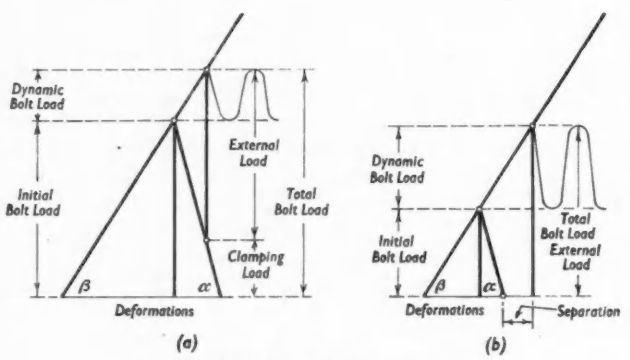
Loosening and Fatigue Strength of Bolted Joints

By M. BOOMSMA, A.M.I.E.Aust.*

This article surveys and comments upon existing knowledge about the loosening of bolted joints under variable tension loads; the effect of bolt length and bolt diameter on loosening; the advantage of using many small bolts instead of a few large ones; the fatigue strength of bolted joints with comparatively rigid abutments. It includes test data from literature and some reference to practical aspects.

A BOLTED joint ceases to function properly when, for example, the elastic deformations of bolts and abutments produced by tightening become inadequate in service. The effect of undertightness can be seen from the load-distribution diagram. In Fig. 1*a*, the bolts have been adequately tightened. For given stiffness factor ratios of bolts and abutments the dynamic bolt load then is directly proportional to the external load applied to the joint and independent of the initial bolt load produced by tightening. In Fig. 1*b* we have the same joint but the initial load is smaller. The same external load here causes the faces of the joint to separate and the larger dynamic bolt load is the difference between external load and initial load. Proper tightening therefore is an effective safeguard against fatigue failure.

The practice of retightening bolts after some running-in indicates that a constant initial load is not maintained in service. The effect of slackening on the safety of a joint can be reduced by increasing the initial load, which also increases the elastic deformations of bolts and abutments. These deformations are very small but their importance will appear from the following.



(*a*) Clamping load at face of joint.
(*b*) Joint opens under the external load.
Tan β is the stiffness factor of the bolt, tan α that of the abutments.

Fig. 1—Elastic behaviour of bolted joints

Stress Loss for a Given Amount of Lineal Loosening

The ratio dynamic bolt load/external load applied to the joint (Fig. 1*a*) indicates how much of the external load is carried by the bolt. Its maximum range is from zero to unity. It can be shown to be :[1]

$$K=\frac{P_d}{P_z}=\frac{C_b}{C_a+C_b}\frac{x}{g} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

P_d=dynamic bolt load.
P_z=external load applied to joint.
C_b=tan β=stiffness factor of bolt.
C_a=tan α=stiffness factor of abutments.

The factor x/g takes into account the point of application of the external load (Fig. 2) and evidently the load-distribution diagram in Fig. 1*a* is only correct when x/g is unity. A few values of K are given in Fig. 3. In general, the stiffer the abutments are relative to the bolts, the smaller the value of K.

When w inch is the amount of lineal loosening and λ_a, λ_b are the respective elastic deformations of abutments and bolt for a given initial load P_i, the load loss is :

$$\frac{wP_i}{\lambda_a+\lambda_b}=\frac{wC_aC_b}{C_a+C_b}=wC_bJ \quad . \quad . \quad . \quad (2)$$

where

$$J=\frac{C_a}{C_a+C_b}=1-\frac{Kg}{x} \quad . \quad . \quad . \quad (3)$$

The factor Kg/x cannot exceed unity, whatever the value of K or g/x. Note that the load loss of joints *A* and *B* in Fig. 3, which have a different arrangement of bolted parts, but equal grip, should be the same providing w is the same.

The bolt's stiffness factor can be calculated from :

$$\frac{1}{C_b}=\frac{l_t}{EA_s}+\frac{l_{sh}}{EA_{sh}}=\frac{l}{EA_r} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

E=Young's modulus.
A_{sh}=cross-sectional area of bolt shank.
A_r=root area of thread.
A_s=stress area of thread.
l_t=length of threaded section below nut.
l_{sh}=length of unthreaded section of shank.
l="active" bolt length based on root area A_r.

The use of the stress area A_s allows for the strengthening effect of the screw thread[5, 6] and is the area at the mean of root and pitch diameters. For ordinary rigid bolts a common value of l is about three-quarters of the grip. For "elasticated" bolts it is greater.

It follows from equations (2) and (4) that the remaining initial stress in the bolt is :

$$S_{ir}=S_i-\frac{wEJ}{l} \quad . \quad . \quad . \quad . \quad (5)$$

Although equation (5) contains the factor J, it applies irrespective of whether the joint opens at the maximum load of each loading cycle or not (e.g. in fatigue testing, to be discussed later) since S_{ir} is the bolt stress after removing the external load. It can be seen that even very small values of w may produce large stress losses because of the magnitude of E.

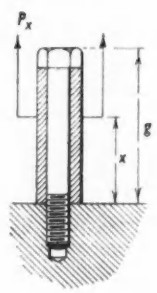
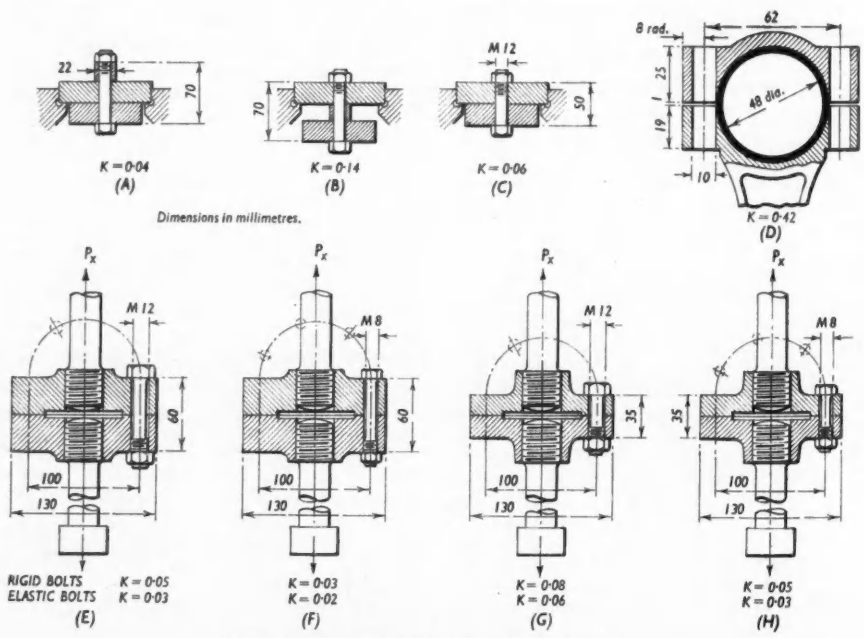


Fig. 2

The clamping load P_c at the face of the joint can be determined from the ratio R of total bolt load P_t and external load P_z, see Fig. 1*a*.



Joints *A* to *C*, Ref. 2; joint *D*, Ref. 3; joints *E* to *H*, Ref. 4.

Fig. 3—Some values of K

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$$R=\frac{P_t}{P_x}=\frac{P_{ir}+P_xK}{P_x}.$$

The external load in terms of bolt stress therefore is :

$$S_x=\frac{S_{ir}}{R-K} \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

The faces of the joint separate when $R=1$ and the minimum value of R therefore is unity. Equations (5) and (6) produce hyperbolas when S_{ir} and S_x are plotted against l and the other factors, w inclusive, are assumed to be constants. For example, the loosening factor w could be regarded as a constant in geometrically similar hydraulic joints of different size but having gaskets of the same thickness. With soft gaskets w is large, but J is small, which provides some compensation. In joints designed for live loads J is often *near unity*. Smaller values of J, however, increase the dynamic bolt load and lead to an increase of w.[2]

It should be noted that E always refers to the bolt material, never to the materials of abutments or gaskets.

Fatigue Strength of the Joint

The fatigue strength of a bolted joint is the sum of the dynamic load that can be endured by the bolts and the dynamic load absorbed by the abutments (Figs. 1*a* and 1*b*). In most cases the condition shown in Fig. 1*b* obtains when the joint is loaded to its fatigue limit. Bolts usually are not tightened against thin flexible tubes or tubular parts, but against parts that are rigid, or at least comparatively rigid. Such joints open at the fatigue limit unless the initial bolt stress is very large. In the latter case the ratio dynamic bolt load/external load could equal factor K.

The separation of the abutments during a fraction of each loading cycle is extremely small, of course, similar to the elastic stretch of the bolts.

It follows from Fig. 1*b* that the fatigue strength of a joint with comparatively rigid abutments is :

$$S_{fz}=S_f+S_i-\frac{wEJ}{l} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

S_{fz} = endurable maximum external load in terms of bolt stress.
S_f = fatigue stress range of bolts (twice the stress amplitude) relative to the initial stress and subject to bending stresses.

The fatigue strength of such a joint appears to change little when portion of the external load is static[2] ; the increase is only K times the static load.

Stress losses may be expected to be uniform in exactly similar joints of different size. Because they would then depend on the ratio d/l (e.g. from considerations of nut creep) the magnitude of w would be directly proportional to d. In actual joints the latter can never be quite the case ; small bolts have a larger lead angle, and surface finish also of the other parts does not necessarily vary with the size of the joint.

Bending stresses also influence the fatigue strength. From the equation of the elastic line, $M\rho=EI$ it follows that in Fig. 4 the bending moment on the bolts is :

$$M=\frac{EI \text{ arc } \delta}{g}.$$

Since $I=\frac{\pi d^4}{64}$, $Z=\frac{\pi d^3}{32}$, and arc $\delta \approx \tan \delta$, the bending stress is :

$$S_b=\frac{dE}{g}\frac{\tan \delta}{2} \quad . \quad . \quad . \quad (8)$$

Actual bending stresses are smaller due to thread clearance, and deflection and plastic deformation of the screw threads. Obviously the reduced value of S_f is not found by simply subtracting S_b.

From the foregoing it appears that the slenderness of the bolts is important. It may therefore be expected that the use of

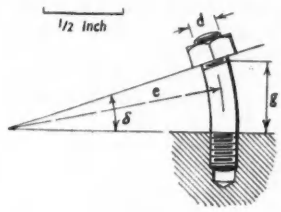
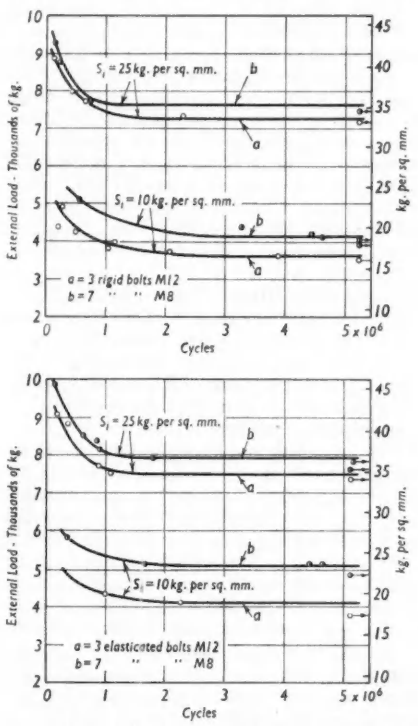


Fig. 4

many small bolts instead of a few large ones, providing they have the same grip, should result in smaller stress losses, smaller bending stresses and therefore in greater fatigue strength.

Fatigue Tests

The flanged joints tested by Thum and Lorenz[4] are those shown in Fig. 3*E* to *H*, and in a third type of joint the centre parts were tubular and integral with the flanges. The bolts were left to their natural loosening. All joints had either three M12 (0·472in) bolts or seven M8 (0·315in) volts. The total root area of the bolts therefore was practically the same, viz. 215·6 and 215·4


S_i = 25 kg. per sq. mm.
S_i = 10 kg. per sq. mm.
a = 3 rigid bolts M12
b = 7 " " M8
External Load - Thousands of kg.
kg. per sq. mm.
Cycles
5 x 10⁶
S_i = 25 kg. per sq. mm.
S_i = 10 kg. per sq. mm.
a = 3 elasticated bolts M12
b = 7 " " M8
External Load - Thousands of kg.
kg. per sq. mm.
Cycles
5 x 10⁶

Grip of bolts 60mm. Static external load 150kg. Initial bolt stress S_i=10 and 25kg per square millimetre. (Thum and Lorenz[4]).

Figs. 5 and 6—Fatigue strengths of flanged joints *E* and *F* in Fig. 3

square millimetres. The bolts in the two sizes were either "elasticated" to 80 per cent of their root area or had full-diameter shanks. Bolt material probably was 0·45 per cent carbon steel, heat-treated, of about 50 tons per square inch ultimate strength. Flanges were a Cr–Mo steel. Uniform and precise tightening was ensured by measuring bolt stretch. Tests were stopped at failure of one of the bolts, which always occurred just inside the nut.

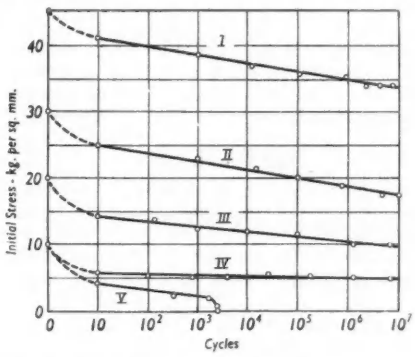
Figs. 5 and 6 show the fatigue diagrams of the heaviest type of joint (Fig. 3*E* and *F*), where side effects from bending of flanges and bolts are unlikely. It will be noted that :

(*a*) The fatigue strengths far exceed the initial loads.

(*b*) The fatigue strengths vary with the initial loads—a clear indication that the joints opened under this loading.†

(*c*) Greater fatigue strength is obtained with "elasticated" bolts or with a greater number of bolts of smaller nominal diameter and the same grip.

A greater number of bolts improves the load distribution on the flanges and should therefore result in greater fatigue strength. However, further tests showed that the M8 bolts and the elasticated bolts suffered less stress loss which is in agreement with the foregoing theory. Congruent results were



Curve I : initial stress 45kg per square millimetre.
Curve II : initial stress 30kg per square millimetre.
Curve III : initial stress 20kg. per square millimetre.
Curves IV and V : initial stress 10kg per square millimetre.
External loading at curves I, II, III and IV : 90 per cent of the respective fatigue strengths.
External loading at curve V : 110 per cent of the fatigue strength. (Würges).[5]

Fig. 7—Loosening of joint *C* in Fig. 3

obtained in the more flexible joints, but at a lower fatigue strength.

Fatigue tests on joints with bolts of different diameter and heavy flanges were also made by Kaufmann and Jäniche[7] and fatigue "size" effect was implied. Results are given in Table I. Both flanges and bolts

TABLE I.—*Fatigue Strength of Joints with Heavy Flanges.*

Static external load in terms of bolt stress 3kg./sq. mm. M10 bolts : assumed initial stress 14·7kg/sq. mm. M20 bolts ; assumed initial stress 14·1kg/sq. mm. Kaufmann and Jäniche).[7]

Size and number of bolts	Fatigue strength in terms of bolt stress, kg/sq. mm
Six stud bolts, M10	16
Six through bolts, M10	19
Four stud bolts, M20...	14
Four through bolts, M20	15

were of 32 tons carbon steel and, therefore, softer than in the foregoing tests. Torque wrenches produced assumed initial stresses of 14·7kg and 14·1kg per square millimetre in the M10 (0·394in) and M20 (0·787in) bolts, respectively. The fatigue stress range of the M20 bolts tested in the conventional manner at low initial stress was 15kg per square millimetre. Stress losses must have been large despite the thickness of the flanges.

Table II shows fatigue test results of single-bolt joints.[2] The (ground) plates were of 32 tons carbon steel, and the M12 bolts of heat-treated 0·45 per cent carbon steel. The fatigue stress range of these bolts was only 7·5kg per square millimetre and practically independent of the mean stress. Between S_i=30—50kg per square milli-

† According to Ref. 4, the fatigue diagrams do not represent the actual nominal stresses in the bolts which should be determined from the stiffness factor ratio. This, however, is not applicable to opening joints.

metre the fatigue strength drops below the initial stress.

The foregoing showed conclusively that the fatigue strength of a bolted joint with rather rigid abutments is related to the remaining initial bolt stress. Little is known about the magnitude of w and how it varies in different applications and under different conditions of loading. Under fatigue loading it appears to be smaller in joints with hard abutments than in the more common kind with rather soft materials.

TABLE II.—*Fatigue Strengths of Joints A, B and C in Fig. 3.*

Type of joint \ Initial stress S_i (kg/sq.mm)	10		30		45		50	
	Calc.	Test	Calc.	Test	Calc.	Test	Calc.	Test
Fig. 3A...	17·5	16·7	37·0	36·1 (21·5)	51·6	49·3 (39·6)	—	—
Fig. 3B...	17·5	16·2	37·0	36·0 (20·8)	45·8	45·0 (44·0)	45·8	44·2 (45·0)
Fig. 3C...	17·5	17·0 (11·0)	37·0	35·8 (21·5)	51·6	49·6 (40·3)	—	—

Constant initial stresses were obtained by repeated tightening of the bolts and measuring the bolt stretch. The values in brackets refer to joints with bolts left to their natural loosening. (Würges)[8]

Causes of Loosening

Goodier and Sweeney[8] found a progressive unscrewing of nuts under variable tensile loading. Causes were shown to be fluctuating changes in the diameter of nut and bolt,[9] and probably deflection of the screw threads. Sauer, Lemmon and Lynn[10] showed that greater dynamic/static load ratios are accompanied by greater loosening; better tightening therefore reduces nut creep.

Bolted joints, per bolt, usually have four pairs of mating surfaces. The real area of contact is small[11] and under variable loading the entire joint "works." Würges[8] and other workers[4, 12] attributed loosening to plastic surface deformation as the most important factor. Fig. 7 gives loosening curves of joint Fig. 3*C* obtained at constant external loads based on 90 per cent of the bolt's fatigue strength. The dynamic bolt load, therefore, increased with the number of cycles. Note that the latter is on a logarithmic scale and that the rate of loosening is practically zero after 10^7 cycles. The magnitude of w can be calculated from equation (5) as about 0·0008in-0·0010in at $S_i=20$ −45kg per square millimetre, assuming $g/x\approx 1$.

Stress losses can be reduced by using a smaller number of parts,[2] better surface finish and harder surfaces,[2] finer thread[4] and by using bolts of smaller stiffness factor.[2, 4] Thread rolling reduces stress loss but with subsequent heat-treatment it is similar to that of cut thread.[2] Spring washers, particularly the saw-tooth type, increase stress loss.[4]

Other causes are permanent set and plastic afterflow. Here rigid bolts appear to behave somewhat better than elasticated bolts.[12] However, the latter are safer because plastic deformation is confined to the smooth shank, whilst in rigid bolts it occurs in the threaded section where stress concentration may produce cracks.

Some Practical Aspects

In practice $S_f+S_i\geq S_y$ in equation (7), where S_y is the torque-tension yield point of the bolts.‡ This may be considered to apply also to high-tensile bolts, which usually come in small sizes. There is little to recommend the use of large high-tensile bolts, of course, unless advantage is taken of their high yield point.

The torque-tension yield point of bolts with cut thread appears to coincide more or less with the pure-tension yield point of the unthreaded bar because of the strengthening effect of the screw thread. This effect is greater on the yield point than on the ultimate strength.

In the general run of work bending moments on the bolts and some slackening cannot be avoided. Allowance should also be made for the fact that bolts of small diameter and relatively low yield point can be easily overstressed in ordinary hand-tightening, either through carelessness or for fear that the joint may not stay tight. Severe plastic deformation may occur. Unless the joint is a mere fastening it must be considered unsafe with such bolts. The latter can be expressed by putting $S_f+S_{ir}=0$.

The risk of plastic afterflow increases with smaller bolt diameters, which can be taken into account by assuming w=constant. We may also write $l=qd$ so that q/E is a rough yardstick for the bolt's torsional flexibility.

On this basis, for a given value of w, equation (7) suggests a minimum practical bolt diameter dependent on the yield point and on EJ/q. However, the effect of EJ/q on the load capacity of the joint diminishes with decreasing bolt diameter. When certain bolts are considered unsafe from a viewpoint of tightening they are so regardless of J and torsional flexibility. The slenderness factor q therefore gains importance with increasing bolt diameter, although at the same time the quotient w/d becomes smaller. Bending stresses may then be the principal strength-reducing factor.

The determination of safe stresses in ordinary hand-tightening can only be empirical and the simplest method is good enough. Deciding, for example, that $\frac{3}{4}$in and smaller bolts hot-forged and machined from 28 tons steel of about 0·5 yield ratio should not be used for major work we obtain $wEJ/q\approx 0{\cdot}375$ $(0{\cdot}5S_u)\approx 12{,}000$ lb per inch, a design constant. A somewhat larger diameter could be adopted for shock loading.

It was assumed in the foregoing that high-tensile bolts are tightened harder ($S_f+S_i\geq S_y$), but it does not follow that the risk of overstressing is greater. A fixed constant results in a minimum practical diameter which becomes smaller with increasing bolt strength, accompanied by a steep increase in safe stress for small bolts. In this case, the percentage increase in safe stress, with increasing bolt strength, differs for bolts of different diameter. The latter is contrary to the practice adopted in certain handbooks.

‡ Initial stresses as found by a shipbuilding company and produced with 10 lb hammers on a 12in spanner were 15·3 tons per square inch in a 2¼in B.S.W. bolt and 14·2 tons per square inch in an M58 by 2 (2·28in metric fine thread) bolt. Material was 32 tons carbon steel. The workmen regarded the bolts as "very tight" and lower stresses are probably more common. Only the fine-threaded bolt could be tightened to 16·4 tons per square inch. Stretch was measured on opposite sides of shank.

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High-Frequency Radio Air Navigation System

Co-operation by the United Kingdom, Canada and the United States, has resulted in a system of Tactical Air Navigation which provides in an aircraft knowledge of its bearing and distance from a ground station. Although specialised in some respects to meet the needs of aircraft carriers, the system has a working resemblance to the system in common use in the U.S.A. The system works in the 962–1215 megacycle or 3cm band. At the ground station a main antenna transmits a modulated series of pulses, which are further modulated by a rotating set of parasite aerials: thus the interrelation of these two modulations will depend on the bearing of the receiver. An aircraft can also obtain its distance along the line of sight from the ground station by operating an interrogator which transmits a pair of pulses of length and interval appropriate to the individual ground station. When one or more aircraft are interrogating the station, the individual pulses from the transmitter are triggered by those received from the aircraft; thus range can be deduced from the time interval between transmission and reception of response. Since the ground station will be responding to all aircraft interrogating it, the aircraft equipment must be able to select the correct, i.e. consistent, answer from the stream of information received; to assist it in so doing, individual interrogators have characteristic and periodically varying pulsing rates. It has been proposed to use this system in North America and this proposal has aroused controversy. The existing high-frequency range is known as VOR/DME; the V.H.F. Omnidirectional Range works in the 30cm band and the Distance Measuring Equipment is essentially similar to the "Tacan" transponder system. The two systems cannot be superimposed, since the transmissions of one would interrogate the other: moreover, the capital charge for the two systems cannot be sustained. Modifications to the aircraft equipment would allow D.M.E. airborne sets to range on "Tacan" stations, and conversely, but the substitution of "Tacan" for V.O.R. is vigorously opposed in view of the technical limitations of the new system. In its range of 200 miles errors in bearings may be 3 deg to 7 deg, so that it would require to allocate wide lanes—say 25 miles—to aircraft flying at the same altitude. Moreover, its line-of-sight radiation renders it useless to low-flying aircraft such as helicopters. There is therefore a call to change, if change there must be, to a more effective system altogether. The U.S. Air Navigation and Development Board is making a study of the technical factors involved.

Assessing the Effectiveness of a Service

By R. SOLT, B.Sc., A.M.I.E.E., A.M.I.Mech.E.*

In determining the effectiveness of a service, one may study the service itself in order to discover avoidable inefficiencies ; a true measure can only be obtained however by studying its effect on the process it serves. For greatest economy, the cost of augmenting a service should be balanced against the additional returns which may be expected. This is illustrated by reference to a case study in which the potential savings had to be assessed on the basis of incomplete data.

A SERVICE function is one which is not itself productive, but which is essential to the operation of a producing unit. Transport is an example of such a service : cranes, lorries and locomotives do not produce anything, but they must work if the plant as a whole is to work.

In the iron and steel industry the necessary handling of materials is prodigious—for every ton of finished steel between 13 and 18 tons of material have to be moved—and it is essential that transport services should be efficient. Because much of steel-making is a batch process, the demand on the available transport changes from hour to hour. This is particularly the case in an open-hearth melting shop : at times all or most of the furnaces will be converting their charge and all is quiet ; but at other times several furnaces may be calling for materials at once and the transport service will be strained to the utmost in trying to satisfy them. Because of the nature of the process, it is impossible to schedule the demand so that cranes, locomotives, &c., are kept evenly employed throughout the day. Moreover, these are major items of equipment and the cost of providing an extra crane or an extra locomotive is considerable. One therefore provides what seems to be the least number which will make for satisfactory working, and almost invariably this results in occasions when the demand temporarily becomes too great for the available equipment.

Most steel works have to cope with these conditions, frequently aggravated by expanding output. Whether services should be augmented is often a major question. The following describes a "composite" case study from experience in a number of works.

The case concerns a melting shop which was served by three scrap loading cranes. There were occasions when all three cranes were working as hard as they could, but several furnaces were ready to accept their charge at the same time and it was impossible to satisfy them all. Some of the furnaces had to be kept waiting, and it was felt that these delays seriously reduced output. A suggestion was therefore put forward that a fourth crane should be commissioned.

Because of the high cost involved it was thought necessary to investigate the position more exhaustively before reaching a decision. In accordance with common practice, a thorough study of the existing cranes at work was undertaken. An observer spent several shifts with each crane and noted the time spent in various activities. He then submitted the findings shown in the table.

Time Study of Scrap Loading Cranes

Activity	Time consumed Per cent
Authorised mealtimes...	6·3
Scheduled maintenance	4·7
Breakdowns	8·1
Sundry delays	5·9
Total enforced idle time...	25·0
Working : loading scrap	61·8
Idle : standing by	13·2

* British Iron and Steel Research Association.

These figures were examined in detail : the proportion set aside for meals was merely the permitted time ; so, also, was the time allowed for maintenance. Time lost through breakdowns seemed excessive, and subsequent investigation of breakdown records showed that some breakdowns could have been avoided. "Sundry delays" proved to be due mainly to drivers starting work late at the beginning of a shift or leaving early. The total time for which the cranes were not available for work, due to these various causes, was 25 per cent, or two hours per shift. It was felt that this should be reduced to about 20 per cent by cutting down on breakdowns and on sundry delays. Apart from this two-hour outage time, the cranes were standing idle for a further hour each shift. The utilisation of the three cranes was only 61·8 per cent ; if a fourth were to be added, each crane would have a utilisation of only 46·4 per cent and would be unemployed—excluding all stoppages and delays—for over two hours each shift. Looked at in this light, the case for an additional crane could not be sustained.

The fact remained, however, that whilst cranes were frequently standing idle, at other times the demand for scrap rose to such a level that they were unable to maintain supply. The question therefore arose whether crane utilisation was in this case the best, or, in fact, any measure of the efficiency of operation.

Utilisation can be defined as the proportion of time for which a unit of labour or equipment is usefully employed ; "100 per cent utilisation" has become a catchword almost synonymous with productivity. In some cases, as in the chemical process industry, major items of plant are continuously working and 100 per cent utilisation is an essential condition of manufacture. In some cases, as in a mass production machine shop, it is both possible and desirable to obtain a high degree of utilisation. In some cases, however, high utilisation need not be of advantage even though it may be possible to achieve. This is true for any service function which is not itself productive, but which affects the productivity of the process it serves. In such a case the effectiveness of the service can only be measured by the satisfaction it gives. This is not a practical measure, but it is possible to gauge the *ineffectiveness* of a service by the delay it causes to the production process which depends on it.

In the present case of the melting shop, the utilisation of the cranes serving it was entirely irrelevant. The time study had proved extremely useful in locating the causes of enforced delays and outages, but its results could not be used as a measure of crane efficiency : the problem hinged on the delay caused to the furnaces when scrap could not be loaded fast enough by the available crane power. Fortunately, furnace operators had standing instructions to log all delays, their duration and their respective causes, so that records of past delays were available. These records showed delays estimated to the nearest 10, 15, 20 and 30 minutes, and thereafter in 15-minute steps. In the course of the 1470 charges which constituted the sample analysed, a total of 175 delays were recorded as being attributable to the magnet cranes. The frequency distribution of these recorded delays is shown in Fig. 1.

Only a small number of short delays had been recorded, although these are actually much more likely to occur than long delays. In practice, however, little importance is

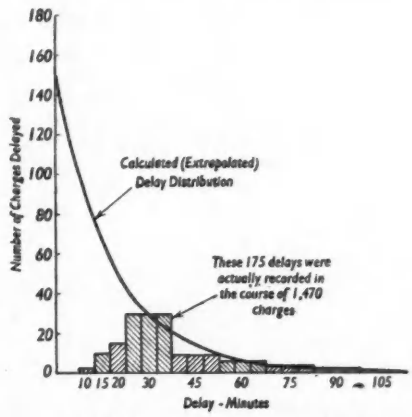


Fig. 1—Distribution of duration of charging delays

attached to delays of short duration and they are therefore liable to go unrecor Short delays are nevertheless important, because they occur often ; and it was necessary to assess their frequency, using as a basis the frequency of longer delays (of half-an-hour and over) which were thought to have been recorded fairly conscientiously. The problem was, therefore, to draw a delay frequency curve through the reliable high delay region, and to extrapolate it back into the short delay region. This curve is also drawn on Fig. 1 and it is evident that the extrapolation could not have been carried out with any confidence from the available data as presented in this figure.

Consideration of the factors which led to delays indicated that the frequency distribution should be a logarithmic die-away curve. In fact, a straight line graph could fairly be obtained if the "Number of Charges

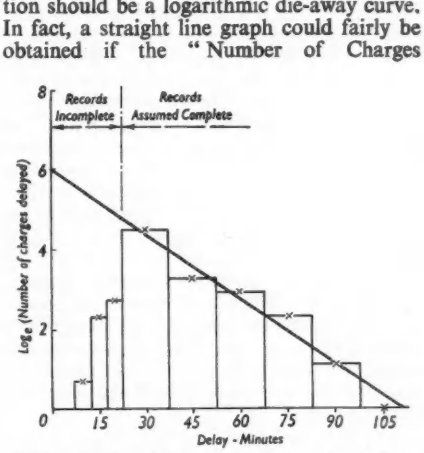


Fig. 2—Charging delays plotted to logarithmic base

Delayed" was drawn to a logarithmic scale, as in Fig. 2. The "theoretical" curve of Fig. 1 represents the same line drawn to a linear scale. It is defined by the equation :

$$\log_e n = k - at$$

where n is the number of charges delayed.
k the intercept on the abscissa (Fig. 2).
a the slope of the line (Fig. 2).
and t the delay time.

How often and how much delay was caused by the scrap loading cranes could be obtained by a simple process of integration, giving :

(*a*) The total number of charges actually delayed $=\frac{1}{a}e^{k}$.

(*b*) The total delay $=\left(\frac{1}{a}\right)^{2}e^{k}$.

With values of a and k read off the graph it was now possible to calculate the required quantities :—

Analysis of Delays Attributable to Scrap Charging Cranes

Number of charges affected by delays	585
Proportion of charges affected by delays (total sample, 1470 charges)	40 per cent
Total delay during 1470 charges	193 hours
Average delay per charge	7·8 min

Three out of every five charges were not delayed at all ; where delays did occur, they exceeded fifteen minutes in less than half the cases. There were occasions when long delays had occurred, but they were relatively rare.

If a furnace is delayed during charging, about half the lost time can be made up during the rest of the cycle. An average charging delay of 7·8 minutes, therefore, meant an average loss of 3·9 minutes on the cycle time. The melting shop in question operated nine furnaces at the rate of fourteen heats per week, so that the total time loss due to the scrap loading cranes was about eight furnace hours per week. The value of a furnace hour could be assessed at £20, so that the potential saving was £160 per week.

The weekly running cost of an extra crane would be made up of :—

	£
Cost of manning (two men per shift)	65
Maintenance	20
Power (the new crane would relieve the existing cranes of work, so that the extra power cost would be small)	5
Total weekly running cost...	£90

Deducting the running cost from the potential saving leaves £70 per week, or £3500 per annum towards the cost of a new crane. In fact this figure is a little optimistic, as some delays would occur even with an extra crane. Even so, these figures provided a good case for the purchase of a fourth crane.

In conclusion, it may be well to summarise the problem in general terms :—

(1) Production delays can be caused by a service on which the main productive process depends. The service function itself may be studied to discover whether the available equipment is operated efficiently, and this can often be assessed on the basis of a time study.

(2) The results of such time studies will show the utilisation of the existing equipment ; if this is low, the temptation exists to regard it as proof that the equipment is adequate. The utilisation of a service function is, however, quite irrelevant : what matters is its effect on the process it serves. The cost of augmenting the service should be balanced against the additional return which may be expected.

(3) The delay caused by a service function can sometimes be assessed even if the available records are only partially reliable. One method for doing this is described : it only applies to a particular case, and other methods may have to be found for different circumstances.

WINCH FITTING FOR A PORTABLE CHAIN SAW.—A new winch attachment has been developed by J. Clubley Armstrong Danarm, Ltd., Abford House, Wilton Road, London, S.W.1, for fitting to the firm's "Fury" or "Whipper" power chain saws. To convert the machine for winching duties the guide blade and chain are removed from the petrol engine drive assembly of the saw and replaced by the drum unit. The winch can be anchored in various ways according to the job and its drum takes 125ft of ¼in wire rope. The makers state that the winch has a lifting capacity of more than ½ ton when fitted to a "Fury" engine and 9 cwt when fitted to a "Whipper" engine.

Effect of Arcing on Air Flow Through Nozzle of a Gas Blast Circuit Breaker*

No. II—(*Concluded from page 252, August 19th*)

By A. A. HUDSON, B.Sc., Wh.Sc., D.I.C.

This article summarises investigations into the influence of the arc upon the air flow in the nozzle electrode of an axial-flow air blast circuit breaker. The mass flow of air through the nozzle during arcing and the static pressure at three points within it have been measured for a supply voltage of 3·8kV. The use of the mass flow ratio during arcing as a criterion in determining similar arc quenching conditions shows that this ratio may be expressed empirically as a function of the quantity $(I/d^{1\cdot5}p^{0\cdot5})$. There is a critical range of this quantity in which a mixture of clearances and failures occur and which separates the region of clearances from that of failures. Regarding the centre of the critical range as the mean critical value of the ratio $(I/d^{1\cdot5}p^{0\cdot5})$, it is possible to correlate this quantity with switch and circuit variables other than I, d and p. So far, these include the rate of rise of restriking voltage and the distance between the nozzle and upstream electrodes (lower gap).

(5.2) *Nozzle Pressure.*—(5.2.1) Method of Representing Nozzle Pressure.—Typical oscillograms of the pressure at three positions within the nozzle are shown in Fig. 11 for (*a*) a one half-cycle clearance, (*b*) a two half-cycle clearance, and (*c*) a failure to clear by the test breaker.

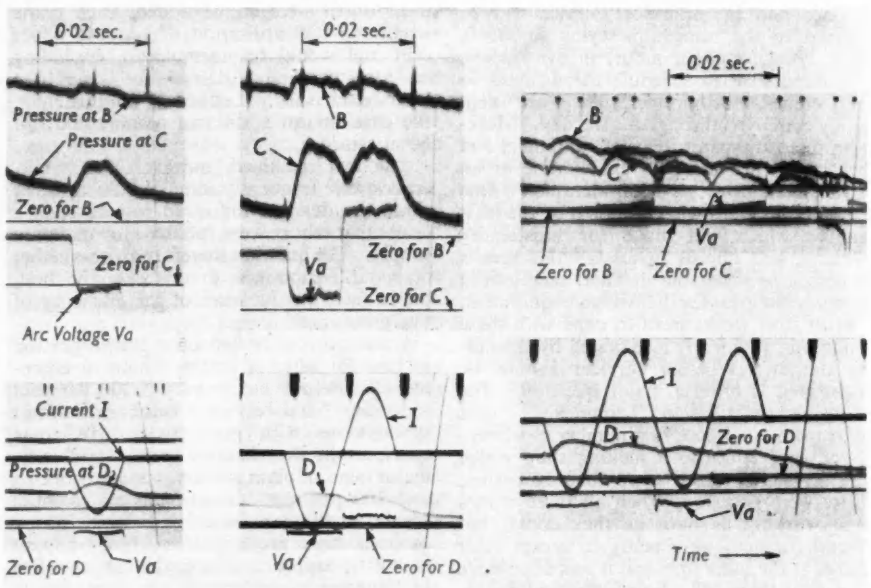
The peak nozzle pressures during the first half cycle of arcing have been determined from the Duddell records and, as in the case of mass flow, they have been expressed in a non-dimensional form by a ratio, defined as follows :—

Peak nozzle pressure ratio during first half cycle of arcing $=\hat{P}_n$, where

$$\hat{P}_n=\frac{\text{Peak nozzle pressure during first half-cycle of arcing (abs.)}}{\text{Arc chamber pressure at the instant of peak nozzle pressure (abs.)}}$$

(5.2.2) Pressure Variation Within the Nozzle During Arcing.—The nozzle pressure ratios for the three holes *B*, *C* and *D* (see Fig. 2 *ante*) have been plotted against the quantity $(I/d^{1\cdot5}p^{0\cdot5})$ for the three values of lower gap in Fig. 12.

By means of data extracted from the nozzle pressure curves for the three recording positions, a further set of curves (see Fig. 13) has been constructed for the case of a lower gap of 1cm, showing the variation of static pressure along the air stream between a point in the arc chamber just upstream of the nozzle to the downstream end of the nozzle. Curves representing the conditions obtaining for various values of the ratio $(I/d^{1\cdot5}p^{0\cdot5})$ between 0 and 500 are given, the shaded area between the ratios 115 and 220 referring to conditions within the critical zone.



(*a*) One half-cycle clearance (*b*) Two half-cycle clearance (*c*) Failure to clear by test breaker

The pressures were measured at positions *B*, *C* and *D* (See Figs. 2 and 12).

NOTE:—The pairs of records above do not necessarily refer to the same tests.

Fig. 11—Typical nozzle pressure records

(5.3) *Nature of Flow Through Nozzle During Arcing.*—With the aid of the values of nozzle pressure and mass flow measured in this investigation it is possible to obtain a fairly clear picture of the nature of the air flow from the arc chamber through the nozzle during the period of current flow. For this purpose the air flow may be conveniently considered from two aspects : first, the flow from the downstream end of the nozzle to the atmosphere and, secondly, the flow in the nozzle entry, that is to say from the arc chamber to the upstream end of the nozzle.

* Based on Report Ref. G/T296 of the British Electrical and Allied Industries Research Association.

(5.3.1) Flow from the Downstream End of the Nozzle.—So long as the nozzle vents to the open air, or into a region where the pressure is lower than that in the arc chamber, as in the tests under consideration, there must always be a mass flow of air from the downstream end of the nozzle, no matter what arc conditions exist. This means that the mass flow from the nozzle can never become negative.

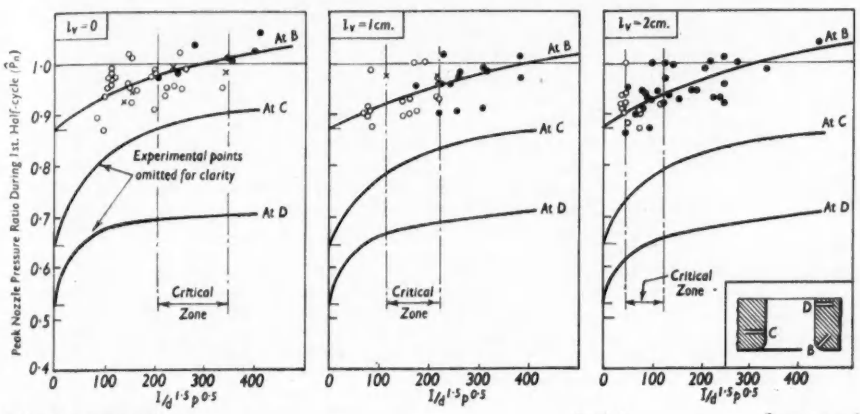
(5.3.2) Flow Reversal in the Nozzle Entry.—The air flow from the chamber to the upstream end of the nozzle, however, may be either positive or negative, depending upon the magnitude of the current, nozzle size and pressure.

Consider the static pressure distribution between the chamber and the nozzle (based upon the experimental results given in Fig. 13) as illustrated in Fig. 14*a* and *b* for two conditions, namely, when the nozzle pressure ratio P_n at any specified instant is less than and greater than 1·0 respectively.

The broken lines represent the condition obtaining with no current flowing. At the start of short circuit, however, the nozzle pressure starts increasing and reacts upon the flow in the nozzle entry (the space *XXYY*), modifying the pressure distribution here as indicated by the full lines.

The direction of flow in the nozzle entry remains positive so long as the pressure here remains everywhere less than the chamber pressure (see Fig. 14*a*), i.e. so long as P_n remains less than 1·0. If the pressure in the nozzle entry, under the influence of the arc, should rise to a value greater than the chamber pressure (see Fig. 14*b*), i.e. if P_n becomes greater than 1·0, the direction of the pressure gradient becomes reversed and the mass of air in the nozzle entry is free to expand back into the arc chamber, giving the phenomenon of "reversed flow."

The nozzle pressure curves given in Fig. 13 show that such conditions probably do, in fact, occur at the higher values of $(I/d^{1\cdot5}p^{0\cdot5})$, as, for example, between the points *B* and *A* for a ratio of 500. It will be observed also that in Fig. 5*b* the value of dp/dt in the arc chamber becomes negative in the second and third half cycles of current, suggesting that, for a circuit breaker are quantitatively represented by the ratio of the minimum mass flow during the half cycle of arcing in portion of each of these half cycles, the pressure in the chamber increases owing to a reversal of flow in the nozzle entry.



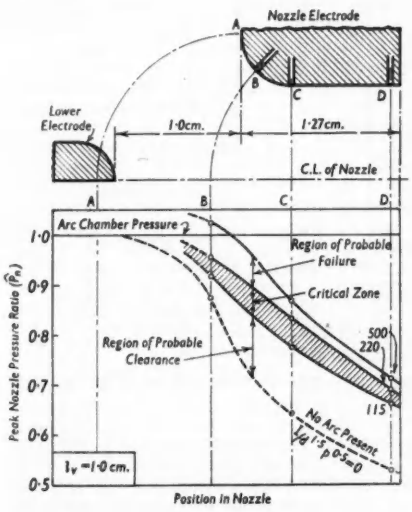
Peak nozzle pressure ratio

P_n = Peak nozzle pressure during first half-cycle, lb/sq in abs. / Arc chamber pressure at the same instant, lb/sq in abs.

O—Clearance in one half-cycle.
×—Clearance in two half-cycles.
●—Failure to clear by test breaker.

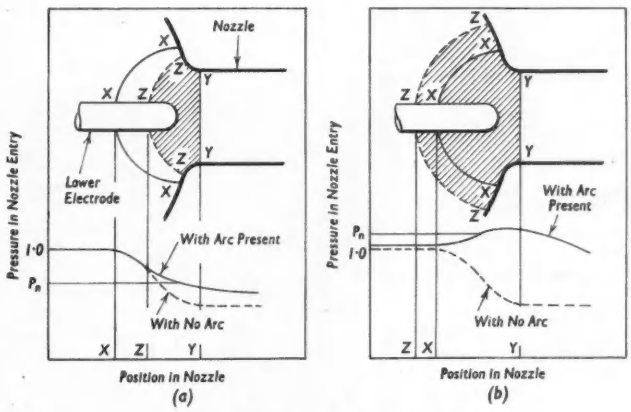
Symbol		Range covered in the tests
I	Current, amperes R.M.S.	1000–8500
d	Nozzle diameter, cm.	1·0–2·5
p	Arc chamber pressure at S.S.C., lb/sq in abs.	35–155
R.R.R.V.	Rate of rise of restriking voltage, volts/micro-second	725 (mean)
l_v	Lower vertical gap, cm (see Fig. 3)	0, 1·0 and 2·0

Fig. 12—Curves of peak nozzle pressure ratio at points *B*, *C* and *D* for three values of lower gap



Data taken from results given in Fig. 12

Fig. 13—Peak nozzle pressure ratio along air stream through nozzle for various values of $I/d^{1\cdot5}p^{0\cdot5}$



(*a*) $P_n \leqslant 1\cdot0$ and $l_v = 0$. (*b*) $P_n > 1\cdot0$ and $l_v = 0$.

P_n = Pressure of the hot gas in the nozzle entry at any specified instant / Arc chamber pressure at the same instant

l_v = Vertical distance between lower electrode and the nozzle.
Shaded area represents hot gas in the nozzle entry.

Fig. 14—Diagrams illustrating extent of hot gas in nozzle entry

Conclusions

The following conclusions are drawn from the results of a series of tests carried out at 3·8kV in which the effect of arcing on the mass flow of air through the nozzle of an experimental air blast breaker has been determined and used as a criterion in determining similar arc quenching conditions for various values of current, from 1000A to 8500A r.m.s., nozzle diameter from 1·0cm to 2·5cm, arc chamber pressure from 20 lb to 140 lb per square inch gauge, lower vertical gap from 0cm to 2·0cm and R.R.R.V. from 170V to 1170V per microsecond.

(1) The effects of arcing on the mass flow of air through the nozzle of an air blast question to the mass flow which exists, at the same pressure level, all other factors being equal, in the absence of an arc. This non-dimensional quantity may be referred to as the minimum mass flow ratio or, for brevity, as the "mass flow."

(2) The minimum mass flow ratio is a function of the current I, the nozzle diameter d, the absolute pressure p in the arc chamber at S.S.C., and the length lv of the arc below the nozzle.

(3) With lv constant the minimum mass flow ratio is a function solely of the other three variables mentioned, combined in the form $(I/d^{1\cdot5}p^{0\cdot5})$,

(4) Increase of lv can be taken into account by a slight increase of the quantity giving the mass flow ratio, which then becomes $(I/d^{1\cdot5}p^{0\cdot5}+k_3lv)$. Within the practical range, however, the effect of lv is small and can be neglected as a first approximation, though its effect on the mean critical value may be considerable (see conclusion (6)). In what follows the minimum mass flow ratio is treated as a function of $(I/d^{1\cdot5}p^{0\cdot5})$ only.

(5) Examination of the curves of mass flow against $(I/d^{1\cdot5}p^{0\cdot5})$ given in Fig. 6 indicates that, treating I, d and p as the only independent variables, there exists a critical zone in which a mixture of clearances and failures occurs, and which itself separates regions where all clearances and all failures have been observed respectively. The width of the zone is probably greater than so far observed.

(6) Regarding the centre of the critical range as representative of a mean critical value—$(I/d^{1\cdot5}p^{0\cdot5})_{m.\,crit.}$—then this quantity can be studied in relation to variables connected with the breaker or its circuit other than I, d and p. Thus it is found that $(I/d^{1\cdot5}p^{0\cdot5})_{m.\,crit.}$ is nearly a linear function of lower vertical gap (see Fig. 8), the value decreasing with increase of gap. Similarly, the relation between $(I/d^{1\cdot5}p^{0\cdot5})_{m.\,crit.}$ and R.R.R.V. is given in Fig. 9 and shows a decrease with increase of R.R.R.V.

The relation between $(I/d^{1\cdot5}p^{0\cdot5})_{m.\,crit.}$ and the system voltage has not yet been studied.

(7) A preliminary check on the possibility of applying the mass flow results reported here to conditions outside the ranges covered in these tests, shows that for a limited set of data, obtained from tests using considerably larger currents, nozzle diameters and pressures (see paragraph 5.1.6) good agreement is obtained with the results in this article (see Fig. 10).

(8) It has been found that the peak pressure ratio within the nozzle during the first half cycle of arcing is also a function of $(I/d^{1\cdot5}p^{0\cdot5})$ (see Fig. 12). The pressure at the throat section of the nozzle (i.e. at *c* in Fig. 2) increases from the value with no arcing, which obtains at the zero value of the ratio $(I/d^{1\cdot5}p^{0\cdot5})$, and approaches an asymptotic value at a ratio of about 500 or 600 with the units used in this report.

(9) The experimental results indicate that, under certain conditions of current, nozzle size and pressure, the static pressure in the nozzle entry may assume a value greater than the arc chamber pressure, thus providing favourable conditions for a local reversal of flow between the chamber and the upstream end of the nozzle. Conditions suitable for a reversal of flow from the downstream end of the nozzle can never exist.

Appendix.—Determination of Mass Flow of Air from a Reservoir when Discharging to the Atmosphere Through a Nozzle.

Consider a reservoir filled with compressed air (see Fig. 1) fitted with a nozzle which is free to discharge to the atmosphere.

Then let

V = Volume of the reservoir.
P = Pressure } of the air in the reservoir with
R = Density } the outlet initially closed.
p = Mean pressure } of the air throughout the reservoir, at a time t
ρ = Mean density } after opening the outlet.
M = The mass of air in the reservoir at time t after opening the outlet.
γ = Ratio of specific heats of air at constant pressure and at constant volume.

Assuming adiabatic expansion of the air in the reservoir, we have

$$p/\rho^{\gamma} = P/R^{\gamma},$$

$$\text{i.e. } \rho = (p/P)^{1/\gamma} \cdot R \quad . \quad . \quad . \quad (1)$$

Now, mass of air in reservoir at time t

$$M = V\rho.$$

Mass of air in reservoir at time $(t+\delta t)$,

$$(M+\delta M) = V(\rho+\delta\rho).$$

Therefore, mass of air escaping in time δt,

$$\delta M = V\delta\rho \quad . \quad . \quad . \quad . \quad (2)$$

But from equation (1)

$$\delta\rho = \frac{R}{P^{1/\gamma}} \cdot \frac{1}{\gamma} \cdot p^{(1-\gamma)/\gamma}\,\delta p.$$

Substituting in equation (2),

$$\delta M = \frac{VR}{P^{1/\gamma}} \cdot \frac{1}{\gamma} \cdot \frac{1}{p^{(\gamma-1)/\gamma}} \cdot \delta p.$$

Therefore

$$\frac{dM}{dt} = \frac{VR}{\gamma P^{1/\gamma}} \cdot \frac{1}{p^{(\gamma-1)/\gamma}} \cdot \frac{dp}{dt} \quad . \quad . \quad . \quad (3)$$

In this expression, V, R, P and γ are constants, so that the expression may be written

$$\frac{dM}{dt} = \text{constant} \cdot \frac{1}{p^{(\gamma-1)/\gamma}} \cdot \frac{dp}{dt} \quad . \quad . \quad (4)$$

Acknowledgments

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Two Early Forms of Nuclear Reactor for Power Generation

Several papers dealing with reactors for power production were presented at the International Conference on Peaceful Uses of Atomic Energy, held at Geneva from August 8th to 20th. Abstracts from two of these papers are reproduced below. In the first paper Sir Christopher Hinton explained how the graphite-moderated, gas-cooled reactor came to be chosen for the first British power-producing pile because this particular design was inherently stable; such a pile did not, therefore, require to be isolated in the interests of safety. Sir Christopher went on to describe the development of this kind of reactor, first at Windscale, and then at Calder Hall. Finally, he examined some of the possible lines of future progress. In the second paper, the authors, D. I. Blokhintsev and N. A. Nikolayev describe the first atomic power station in the U.S.S.R., which began generating electricity on June 27, 1954. It is a pressurised, water-cooled, uranium-graphite reactor giving an electrical output of 5000kW.

Graphite-Moderated, Gas-Cooled Pile and its Place in Power Production*

IN every engineering development there is an element of chance which may sway the balance between the choice of one design or another. When I was asked to undertake responsibility for the production of fissile material in 1946, it was the intention that Great Britain should build reactors of the original Hanford type. This pile is graphite-moderated and water cooled and it cannot be made inherently stable if operated solely on a natural uranium fuel. Because of this fact very large safety distances were considered essential. These safety distances are permissible in large Continental areas, but in the thickly populated United Kingdom it was difficult to find suitable sites. Therefore, it was thought that we would do better to choose a type of pile which was inherently stable and which did not demand isolation in the interests of safety. It was for this reason that our efforts were turned towards the graphite-moderated, gas-cooled pile. It was realised that in order to bring the blower power (for circulating the coolant) down to the lowest practicable level it would be necessary to operate the pile under pressure and that this would introduce problems of the design of a pressure shell, of fuel element changing gear and of control rod operation. Although solution of these problems was certainly possible, it was clear that they would take time to solve. But in the course of these preliminary studies it became apparent that although a pressurised gas was necessary for really economic operation, it would be possible to operate at atmospheric pressure if sufficient flattening of the neutron distribution across the pile was done. This meant that an immediate and simplified solution of the problem of bulk plutonium production could be achieved by building graphite-moderated piles cooled with air blown through them at atmospheric pressure. It was therefore largely force of geographical circumstances which led us to the graphite-moderated, gas-cooled reactor. If Great Britain had not been such a densely populated country and we had easily been able to find sites where safety distances could be met, we probably should have followed the American lead and built graphite-moderated, water-cooled reactors.

The first reactors built for plutonium production at Windscale have been described in earlier lectures elsewhere.†

The Calder Hall Piles

In the Windscale piles all the heat is wasted. While they were being built study of the graphite-moderated, pressurised, gas-cooled pile from which power would be produced was continued, and in 1953 it was decided that it was reasonable and prudent to proceed with the construction of such piles at Calder Hall in Cumberland. In principle, the pile is shown in Fig. 1. It will be seen that the core of the reactor is surrounded by an octagonal shaped concrete biological shield several feet thick, and this shield is protected from thermal and radiation effects by a thermal shield made of 6in mild steel plate.

Induced draft air cooling is supplied to the space between the thermal shield and the biological shield and the outlet air is exhausted 200ft above ground level from the two stacks on the pile building.

The mass of graphite moderator weighing over 1000 tons is contained in a cylindrically shaped pressure vessel. The machined graphite

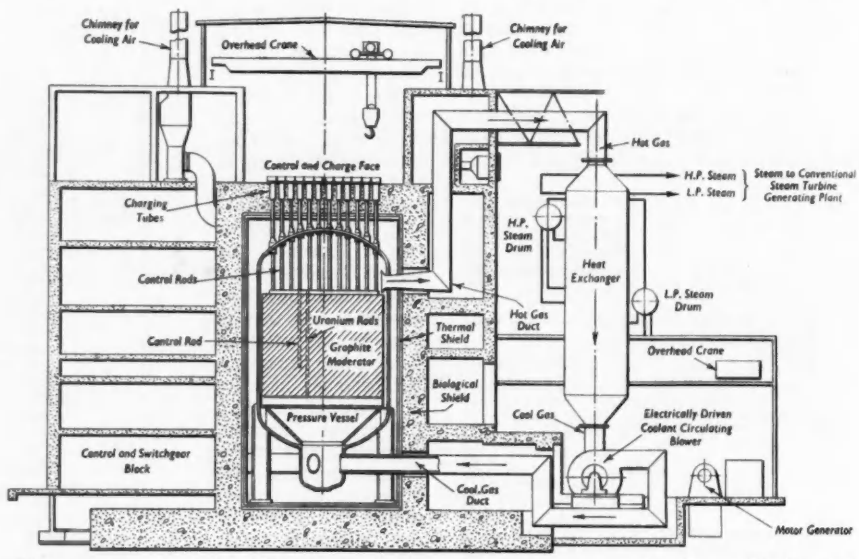


Fig. 1—Section of a Calder Hall pile, showing the reactor core, pressure vessel and one of the four heat exchangers

* Abstract. Paper presented at International Conference on Peaceful Uses of Atomic Energy. Geneva, August 8–20th.

† As reported in The Engineer, March 5, 1954, pages 357–360.

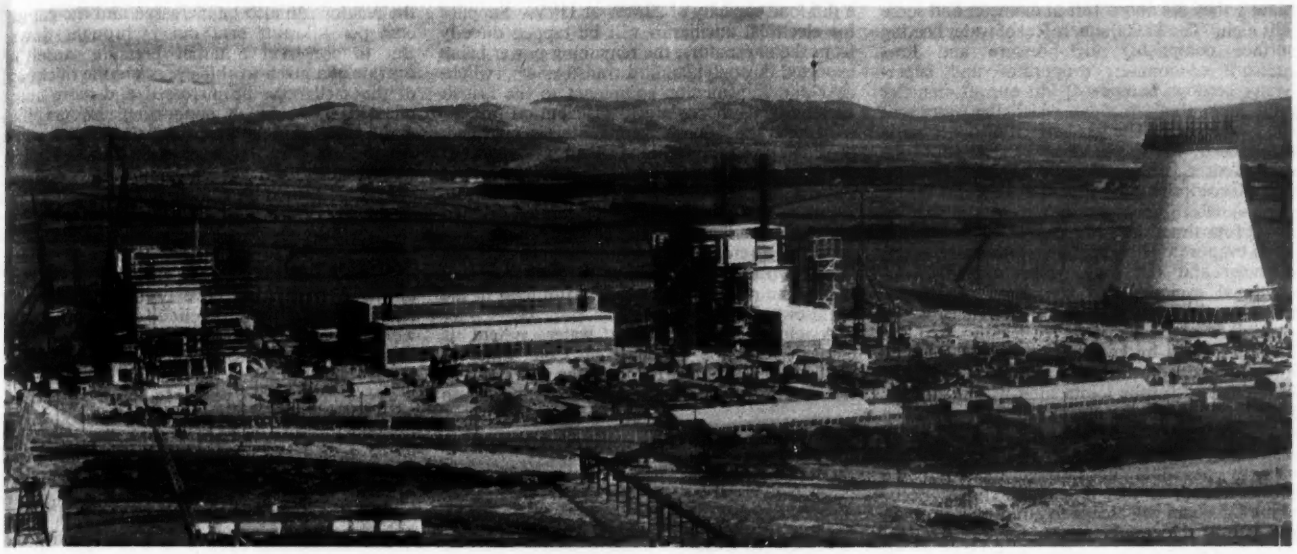


Fig. 2—The nuclear power station under construction at Calder Hall, viewed from Windscale. Two reactors, the turbine hall and one of the two cooling towers can be seen

blocks have vertical uranium charge and control rod channels, the adoption of vertical channels simplifying the graphite structure and making the design of the coolant circuit more convenient. The weight of the graphite is taken on a "diagrid" structure which consists of an I-section ring girder spanned with steel girders forming a rectangular lattice. Across the members of the "diagrid" lattice are bolted 4in thick steel base plates which have holes in them to coincide with the channels in the graphite. These base plates support the graphite through a number of races, which allow for differential thermal expansion of the "diagrid" and graphite. The weight of graphite and "diagrid" is taken by brackets directly through the walls of the pressure vessel on to ten inverted A-frames which rest on the thermal shield. These A-frames are loosely bolted to the brackets on the pressure vessel and on to the thermal shield, the three contact surfaces of each A-frame being radiused (Fig. 3). In this manner allowance is made for radial thermal expansion of the pressure vessel and "diagrid," when the A-frames roll slightly out of the vertical and the bolts ensure that the rolling surfaces do not slip.

The pressure vessel is of 2in welded steel plate and is about 40ft in diameter and approximately 60ft high. The construction of the vessel provided a novel and interesting job. Fabrication was carried out on the site, all parts (except the inlet manifold) arriving piece small. Extensive site welding facilities were set up and the vessel was built up into five main sections, namely, the bottom dome, the two parallel centre sections, the "diagrid" and finally the top dome. As each section was completed it was transported to the lifting area, where a 100-ton crane was used to hoist the sections (Fig. 4) and to lower them through the pile vault roof, the final welds being completed *in situ*. Each butt weld was radiographed and all important fillet welds were examined by crack detection techniques. The task of stress-relieving the completed vessel was achieved by radiant heating, which required a peak electrical load of about 1½MW. The vessel temperature was brought up to over 550 deg. Cent. and held there for eight hours before being allowed to cool slowly and evenly.

The vessel was then subjected to pressure test. The use of hydraulic testing techniques would have overloaded the structure and for this reason a pneumatic test was carried out. A constant check on the behaviour of the vessel by means of strain and other gauges was maintained throughout the test and formed an important part of it.

The final test was under vacuum at one-tenth of an atmosphere pressure and was done by means of the large rotary vacuum pump which is part of the operational equipment required for exhausting the vessel when charging or changing the CO_2 coolant.

The reactor charge and discharge arrangements are accommodated on the pile vault roof along with the pile control and shut-off gear. Emerging from the reactor top dome are the charging tubes, which terminate at the upper surface of the pile vault roof. An overhead crane lowers the charge chute into the desired charging tube, and the charge machine supplies fuel elements from a magazine. Conversely the discharge machine removes spent fuel elements by withdrawing them up the charge chute and placing them in a basket, where they are kept cool. The basket is lowered into a coffin at the bottom of the discharge well, the coffin lid is automatically positioned and the coffin is withdrawn from the discharge room to be transported to the cooling pile pond.

Fig. 3—Adjusting a pressure vessel support leg in No. 1 reactor at Calder Hall. Note the radiused bearing face of the right-hand leg.

The control rods and shut-off rods are made of stainless steel tube lined with boron steel fillers and are suspended through the roof of the pile.

The hot CO_2 coolant is led away from the top of the pressure vessel by circular mild steel ducts of 4ft 6in diameter to the four heat exchangers which are situated at the corners of the pile building. The cool CO_2 coolant from the base of each heat exchanger is boosted by four main blowers and returned to the inlet manifold at the base of the pressure vessel. Motorised isolating valves of the wedge gate type are included in each hot and cold duct, and flow cascades are fitted at the bends in the ducts. The problem of accommodating the large thermal expansions between the pressure vessel and the heat exchangers under various conditions of operation was solved by the use of "hinged bellows" in the ducts. The duct flexibility is obtained from the bellows, which are of welded steel plate, while the thrust due to the internal pressure of the gas is taken by the pin joint in the bellows assembly. The whole of the duct structures are carried on spring type constant-load supports.

The four CO_2 coolant blowers are of the single-stage centrifugal type with an overhung impeller. The overhung impeller arrangement has the advantage of requiring only one gland and it has the additional advantage of facilitating an arrangement in which the gland and bearings can be so located that access to them can be obtained without exposure to radiation which is above tolerance level. The gland is of the face seal design.

It was decided that control of the mass flow of coolant could best be carried out by controlling the speed of rotation of the blowers in preference to varying the static pressure of the coolant system as a whole, thus the d.c. motors, which develop some 2000 h.p. each, are supplied from motor generating sets in the blower house, which permit the blower speed to be varied over the range of 10 : 1 on the Ward Leonard system. About 2 per cent of the mass flow through each blower is taken from the downstream side of the blower, filtered and reintroduced to the system on the upstream side of the blower with a view to preventing the accumulation of graphite dust and iron oxide in the coolant system. A constant check is kept on the water content of the coolant, which is kept down by alumina drying units which hold the dewpoint of the CO_2 below the necessary limit. As in the Windscale piles, continuous monitoring of the coolant gas stream for the detection of burst fuel elements is also carried out.

Over 20 tons of carbon dioxide are required to complete the filling of the reactor and coolant circuits. Charging is carried out by exhausting the system and then admitting CO_2 which is generated from eight standard converters charged with blocks of solid carbon dioxide. Purging by repeated charging and discharging is necessary in the first filling.

Each of the four heat exchangers is contained in a vertical steel pressure shell of 1 $\frac{1}{16}$in steel

plate ; they are about 18ft in diameter and some 70ft high. The 30,000 square feet of water heating surface comprising high-pressure and low-pressure economiser, evaporator and superheater sections is made of 2in overall diameter mild steel tubing, through which the water and the steam pass. The gas surface of the tubes is extended by the use of elliptical steel stud tube construction. Flow in the evaporator sections is by forced circulation from electrically driven pumps, which maintain a circulation rate of about four times the steam output of the section. Each evaporator has a single steam drum, 4ft in diameter and 18ft long, which contains conventional cyclones and scrubbers. Particular attention has been given to minimising the possibility of steam or water leaking into the coolant circuit by keeping the number of tube joints contained within the pressure shell to a minimum. All tube joints sited within the first heat exchanger to be assembled were subjected to an abnormally high-pressure test, followed by a stringent vacuum test. The ends of each tube element pass separately through a sleeve in the pressure shell, so that if leakage should occur at a joint steam will escape to atmosphere. As in the case of the reactor pressure vessel, the final assembly of the heat exchangers was done on site. Each heat exchanger arrived in nine main sections consisting of the dished ends, the six circular centre sections and the skirt. After the heat exchangers were assembled and inspected the final welds were stress relieved and the heat exchangers were lifted on to their concrete plinths, using a pair of 100-ton gin poles (Fig. 5).

The dual-pressure steam system which is used obviously adds complexity in the design and operation of the station, and it was adopted only after careful consideration. The fixed point in the design of a graphite-moderated gas-cooled reactor is the temperature which can safely be achieved in the outgoing gas from the reacting core. This temperature depends on the design and materials of construction of the fuel elements, the possibility of chemical reaction between coolant and moderator and on the size and design of the pressure vessel which encloses the reactor.

Having decided what coolant outlet temperature can safely be achieved, it is obviously possible to get the maximum output from the reactor for a given expenditure of power in the circulating blowers by making the inlet temperature of the gas entering the reactor as low as possible. This can clearly be done by adding cooling surface in the heat exchangers. But if an attempt is made to reduce the temperature of the coolant below a reasonable level, the heat abstracted will be of too low a grade to be used in the thermodynamic cycle for power production ; the bottom slice of heat removed from the cooling gas will have to be rejected to drain. Thus thermodynamic efficiency would be reduced by endeavouring to increase reactor rating. The inlet temperature of the coolant to the reacting core is therefore fixed by the minimum temperature acceptable in the thermodynamic cycle.

Reactor rating can therefore be kept up by generating steam at a low pressure. However, it would not be economical to raise all the steam at a low pressure, since by doing this the capital cost of the turbo-alternator would be increased and the thermodynamic efficiency would be reduced. These considerations lead to the adoption of a dual-pressure steam cycle. It would be possible to consider a three-pressure steam cycle using separately fired superheaters for the high-pressure steam, but such additional complications do not at present seem to be justified.

The steam is taken to the generator house, which is situated between the pile buildings (Fig. 2), where four turbo-alternator sets are installed. The turbines are two-cylinder reaction machines of established design. The l.p. cylinder has twin exhausts which discharge into a surface condenser operating at 1¾in Hg. absolute pressure, i.e. at a temperature of about 38 deg. Cent. The condensate is passed through a de-aerating plant and the steam cycle is completed by the h.p. and l.p. feed water pumps, which return the water to the economisers. Each turbine is directly coupled to a 3000 r.p.m. air-cooled alternator of standard design and having a full-load capacity of 23MW at 11kV. Supplies for electrical ancillaries will be tapped directly from the alternators, the remaining power being exported through standard transformers, switchgear and transmission equipment to the British Electricity Authority's grid distribution lines.

A separate "dump" condenser is provided, in which up to the full-load steam production of the heat exchangers may be condensed without passing through the turbines. The condensate from the dump condenser is de-aerated and fed back into the heat exchangers. The dump condenser is essentially for use during start-up and shut-down of the plant ; but, if required, it will permit the reactors to be run at full load in the event of turbine outage.

A closed-circuit cooling water system is employed for the condensers. Cold water at about 21 deg. Cent. is fed from the cold pond to the suction basin, where four electrically driven

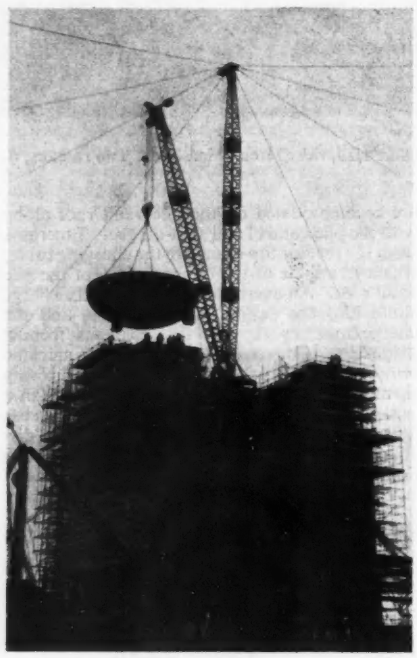


Fig. 4—The pressure vessel base of No. 1 reactor at Calder Hall

pumps send the water to the condenser battery. The hot water at a design temperature of 30 deg. Cent. is fed to the sprays in two natural draught cooling towers, from where it returns to the cold side pond. The cooling towers, which are somewhat larger than normal, being 290ft high and 220ft in diameter at the ring beam, are each capable of cooling 3,000,000 gallons of water per hour by 10 deg. Cent.

Future Developments for Power Production

It is shown in the White Paper published by the British Government in February, 1955, that when a reasonable allowance is made for the value of the plutonium produced as a by-product in graphite-moderated gas-cooled reactors electrical power can be generated from them at an all-in cost of 0·6d. per unit sent out. This estimate of cost is based on the use of techniques which are at present known. With the development of better techniques it should be possible to reduce the generating cost even further. The graphite-moderated gas-cooled reactor has tremendous advantages, in that it is extremely safe in operation, it can employ natural uranium as a fuel, and it does not demand the use of any exotic materials in its construction. It is therefore worth while to consider what further developments can be made in this type of reactor which will enable it to produce electrical power at even lower costs.

One of the limiting factors in the design of reactors of the Calder Hall type is the size of pressure vessel which can reasonably be constructed. If the volume of the pressure vessel is increased then the total thermal capacity of the reactor can also be increased and the capital cost per kilowatt sent out is brought down. But to construct a larger pressure vessel to operate at a given working pressure the thickness of the shell must be increased and more complicated problems of supporting the graphite and transmitting the load through the shell walls are introduced. In the case of Calder Hall it was decided that the maximum thickness of plate which could be welded on site was 2in, and so the size of a cylindrical pressure vessel which could withstand the necessary pressure was fixed immediately. If the working pressure had been reduced the diameter of the core and the output of the reactor could have been increased, but the pumping power for circulating the coolant would have gone up. It is hoped that future developments will include the welding of thicker gauge plate, possibly up to 3in, enabling the use of larger pressure vessels to become practical. The thicker plate would alternatively allow working pressures to be lifted for a given pressure vessel size and this would result in a lower blower power being required to remove a given amount of heat. Another line of approach is to use a spherical pressure vessel which, with a given plate thickness, could be made nearly twice the diameter of a cylindrical container. Considered purely as a problem of pressure vessel design, the sphere offers very great advantages, but it gives rise to difficulties in the support of the graphite structure of the moderator within it. Also the costly biological shield is larger for a given total thermal capacity, but this difficulty may be alleviated by incorporating the biological shield in the pressure shell.

The search for a better reactor coolant is continuous, but, as happens so often in engineering, a compromise between various conflicting requirements must be accepted. Neutron economy is one of the main problems of reactor design and parasitic neutron losses to the coolant must be small, while due consideration must be given to the characteristics of the coolant as a moderator and under conditions of irradiation. The coolant must be compatible with the circuit components such as the can metal, the pressure vessel and the moderator, while (since defects of canning cannot be absolutely eliminated) its chemical affinity for the fuel itself must not be overlooked. One of the most suitable coolants is helium which, besides being chemically stable, has a high specific heat and offers a negligible capture cross section to thermal neutrons. The main objections to its use in Great Britain are the high cost and the fact that it is not an indigenous material.

Carbon dioxide, on the other hand, is cheap and readily available, while its neutron capture cross section is entirely satisfactory. In addition, it is fairly stable chemically under Calder Hall pile operating conditions, where it does not react with the graphite moderator to any important extent.

Nitrogen is not attractive as it is a poor coolant, the circulation of which would absorb an unduly high proportion of the energy generated, while its neutron cross section is high. Hydrogen, on the other hand, offers interesting possibilities as a coolant. First, it would act as a moderator resulting in a reduction of graphite and structural costs, while a loss of coolant would reduce the pile reactivity. Secondly, it would only require about one-tenth of the blower power required for CO_2. It reacts with uranium at certain temperatures, however, and this might cause serious trouble, because it can pass through the can by diffusion even while the can remains sound. Diffusion of the hydrogen into the structural steel of the reactor may also be a cause of trouble.

The use of a slightly enriched uranium charge may also lead to economies. It may make it possible to use canning materials which have previously been rejected because of their high neutron cross section. The use of such materials may make it possible to use higher fuel element operating temperatures with safety and so to achieve higher thermodynamic efficiencies. A slightly enriched uranium charge towards the outside of the reactor core enables flattening of the neutron flux distribution across the core to be carried out, which, in turn, increases the total thermal capacity of the pile and, hence, the electrical output of the station.

In the pure engineering field, there can be no doubt that the design of heat exchangers can be considerably improved and cheapened. The problem of raising steam by transferring heat to the water from a perfectly pure and clean gas has never before had to be considered on a large scale. The stud tube extended surface heat exchanger which is used at Calder Hall had the tremendous advantage that this type of heat exchanger surface was already established industrially and was in mass production. It is not an ideal type of extended surface for the absorption of heat from a completely pure gas. Each one of the Calder Hall heat exchangers (Fig. 6) weighed some 200 tons and the problem of transporting the sections, assembling them on the site and lifting the complete heat interchanger into position caused many anxious problems. There is no doubt whatever that a cheaper, lighter and more compact heat exchanger could be developed to deal with the problem.

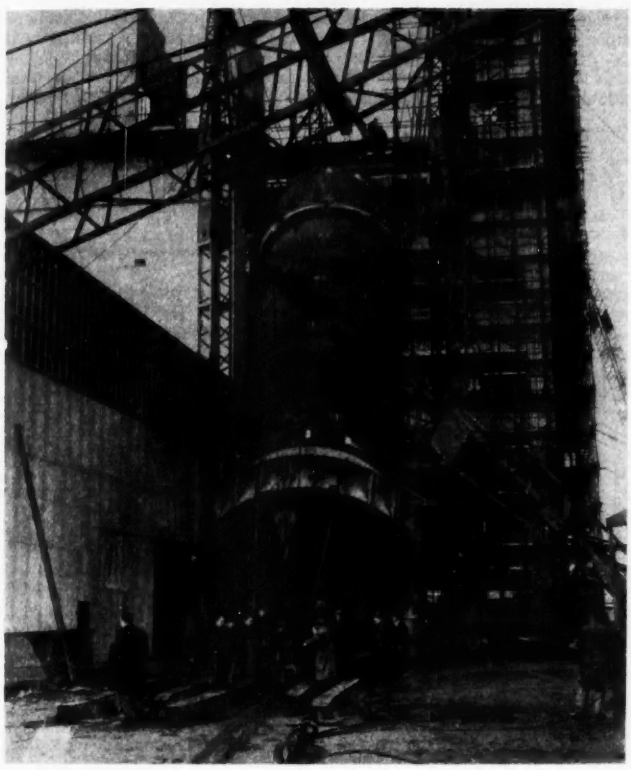


Fig. 5—The final lift of a heat exchanger using two 100-ton gin poles. No. 1 reactor, Calder Hall, with blower house on the left

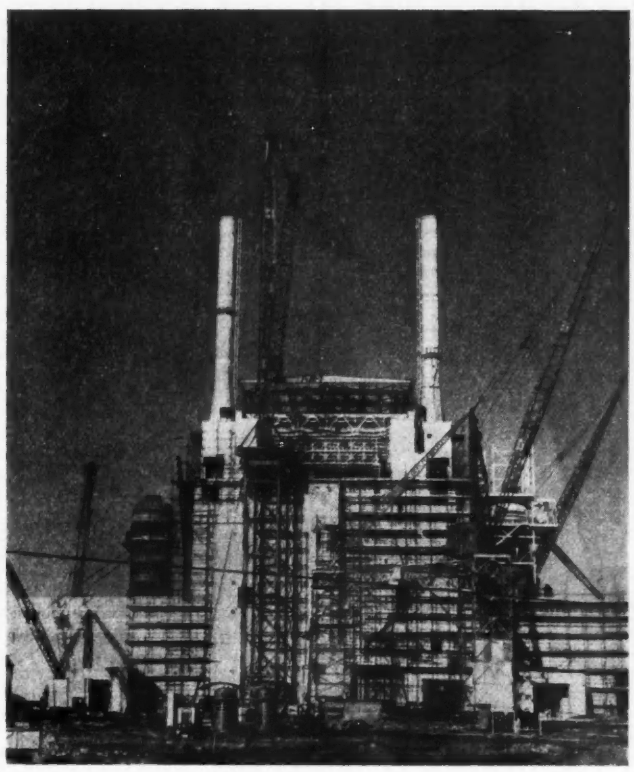


Fig. 6—No. 1 reactor at Calder Hall. Two of the four heat exchangers can be seen. The space between the thermal and biological shields is air cooled, the air being exhausted up the stacks..

The British White Paper Plan

The first reactors which are at present being built may have shortcomings, but they have the advantage that they are inherently safe and that they can generate electricity in large quantities to a guaranteed programme and at prices comparable with a modern conventional power station. They cannot stand on their own and are competitive only when there is a market for the by-product plutonium ; this market must and can be found by recycling or by use in advanced types of reactors, culminating in the fast reactor.

A careful and cautious estimate has been made of the value which can reasonably be accredited for the by-product and, as has been stated already, the cost of electricity from the initial stations has been calculated to be not more than 0·6d. per unit sent out ; reduction in capital and fuel costs should progressively improve the figure.

As already pointed out, it is on the construction of reactors of the graphite-moderated, gas-cooled type that the first stages of the British programme for the development of industrial power are based. The programme starts with the construction of two gas-cooled graphite-moderated stations, each with two reactors, on which construction will begin about mid-1957 and they should come into operation in 1960–1961. The construction of two further stations would begin about eighteen months later, in which the reactors would be of a similar type to those in the earlier stations but they should show an improved performance, particularly in heat rating. The total electrical output from these four stations, which should be in operation by 1963, should be between 400MW and 800MW. By 1960 four more stations should start construction, followed by four more eighteen months later, and when they are all in operation, by about 1965, the eight stations in this group should supply well over 1000MW. The first four of this group may well be developments of the gas-cooled graphite-moderated type, while the last four may be of the liquid-cooled type, which may then have been developed sufficiently to be economically satisfactory. The new stations will have a higher capital cost but lower running costs than the conventional station and they will be run as base load stations at a high load factor of possibly 80 per cent.

It is reasonable to think of nuclear reactors in an ascending scale of specific heat rating of their fuel elements. At the bottom of this scale is the graphite-moderated, gas-cooled reactor of which we have been talking. It is essentially a heavy, land-based reactor, using low specific ratings, but economical because it does not need to make use of expensive and exotic materials of construction. It can, perhaps, be regarded as the slow-speed reciprocating engine of the reactor world, reliable and almost conventional in design.

At the other end of our reactor scale we have the fast fission reactor, very much more highly rated and using expensive and rare materials of construction. High ratings are necessary in order to make this reactor economical because the fissionable material which it uses as a fuel is extremely expensive. It can perhaps be regarded as the gas turbine of the nuclear reactor world.

In between these two extremes are dozens of alternative types of reactor making use of fast neutron, intermediate neutron or thermal neutron velocities ; using no moderator or light water, heavy water, beryllium or graphite as moderators ; using gases, water, hydrocarbons or liquid metals as coolants in any combination that can be imagined.

Which of these reactors will at future dates be found to be economical is more than can be safely predicted to-day. We in Great Britain are attacking the two ends of the scale ; we have designed the graphite-moderated, gas-cooled reactor which will soon be producing large quantities of industrial power at Calder Hall, and we are building the fast reactor at Dounreay. Between these two extremes we are applying our resources at those intermediate points which appear from time to time to offer the greatest promise.

The development of highly-rated reactors is essential because such reactors are needed to burn the by-product plutonium produced in the reactors of conservative rating which are built as the first step in our industrial programme. It would, however, be a great mistake to assume that these conservatively designed reactors of the graphite-moderated, gas-cooled type have only a limited future. With development, the reciprocating steam engine held its own over a period of nearly 200 years as an economical prime mover, and the simplicity and reliability of the gas-cooled reactor will entitle it to a similar place in the history of nuclear power.

The First Atomic Power Station of the U.S.S.R.‡

This 5000kW Russian atomic power station is based on a pressurised water-cooled thermal uranium-graphite reactor with a rated heat-generating capacity of 30,000kW. The average flux of neutrons is 5×10^{13} neutrons per square centimetre per second. The atomic fuel is enriched uranium containing 5 per cent of U235, the total charge being 550kg. The heat transfer system consists of two circuits : the water of the first circuit, which circulates through the reactor, is under a pressure of 100 atmospheres and gives up its heat through a system of heat exchangers to the water of the second circuit, which, on being transformed into steam, drives a 5000kW turbo-generator. The use of a two-

‡ Abstract. Paper presented at Conference on Peaceful Uses of Atomic Energy. Geneva, August 8th.

circuit system of heat transfer eliminates the possibility of radioactive contamination of the turbine and its connections.

The fuel elements are formed by the annular space between the inside steel water circulation tube of the first circuit and the thin-walled outside tube which keeps the fission fragments from penetrating into the gas filling the reactor. The annular space contains enriched uranium in the form of a special alloy, which ensures good thermal contact and stability in the neutron field.

A general idea of the design is given in Fig. 7. The reactor is encased in a hermetical cylindrical steel jacket mounted on a concrete foundation. The jacket is filled with graphite brickwork, with proper clearance. To avoid burn-out of the graphite the jacket is filled with helium (or nitrogen). A total of 128 fuel channels pierce the central part of the graphite brickwork. Each fuel channel is a long graphite cylinder containing thin-walled steel tubes carrying the primary circuit water. The water passes through the upper head of the channel connected with the inlet and outlet headers, then runs down through the tubes and returns upwards, flowing over the surface of the uranium fuel elements. The uranium fuel elements form a cylindrical (150cm in diameter and 170cm high) active zone of the reactor, enclosed by a graphite reflector.

The flow and temperature of the water are recorded for each channel. The indicating instruments are located on the central panel and are connected with the safety rods which stop the chain reaction when the water flow exceeds the prescribed limits or when the temperature rises above the allowed level. At a pressure of 100 atmospheres water boils at 309 deg. Cent. If the temperature of the water in the channel reached this level its boiling would cause a sharp heat removal decrease and consequently overheating and possible destruction of the fuel element.

It is therefore very important to control the outlet temperature of the water since this reflects the conditions in the channel. In practice this is effected by means of a scanning light signal indicating the channels where the temperature of the water is above the prescribed limit. There is, in addition, a separate plug panel for measuring the absolute temperature of the water in any desired channel.

Temperature measurement is supplemented by water flow measurement. The latter is effected by flow meters mounted on a separate board, and the warning light signals if the water flow should exceed the prescribed limit are sent to the central panel. A decrease in the flow of water in a channel leads to a rise in the outlet temperature. An increase in the water flow in a channel indicates a rupture in tubes of the channel or its connections. All these deviations are dangerous and lead to a shut-down of the reactor (termination of the chain reaction) by means of the safety rods. To prevent rapid filling of the reactor with water in case of a rupture of channel tubes, which would lead to a rapid rise of reactivity, each channel is equipped with a cut-off device and a non-return valve to interrupt the flow of water from the header. A small water flow remains to remove the residual heat produced by radioactive decay of the fission products. The radioactivity of the water and gas in the reactor is constantly measured so that any rupture in the fuel elements would be indicated by a rise of the activity. By drawing off the gas near the channel it is possible to determine, by the moisture content, the ruptured channel if the leak is not big enough for the flow meters to record it. In addition to channel flow meters the central panel has indicators showing the total flow of water through the reactor, its pressure and temperature in the inlet and outlet headers.

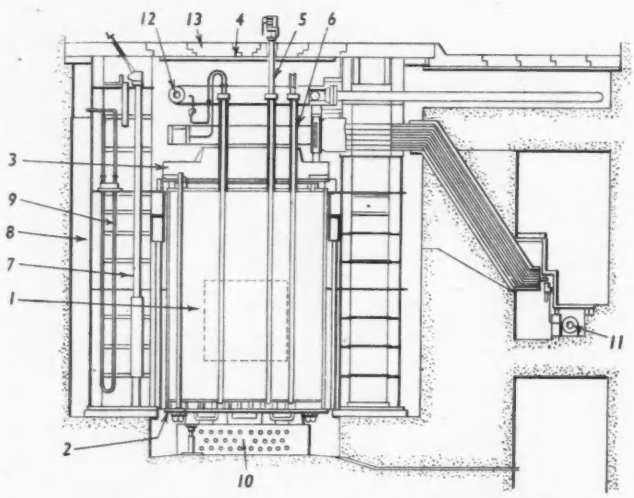
To compensate the excessive activity of the reactor eighteen boron carbide rods are installed in the reactor, six near its centre and twelve at the extremities of the active zone. These rods can move in special water-cooled channels with a separate cooling system. There is a separate cooling system also for the graphite reflector. By means of wire ropes and servo-motors these rods are moved vertically and their position is registered at the central panel on a special board. Special measures have been taken to prevent the operator from accidentally lifting these rods too quickly. With these rods it is possible to regulate the outlet temperature of the water in the fuel channels.

The total submerged length of all the shim rods in the operational régime of the reactor indicates the total excess of its reactivity, and consequently the total above-critical quantity of atomic fuel. Therefore the fuel quantity may be expressed in linear centimetres. A special graduated scale indicates the value of each centimetre of rod with regard to its influence on the reactor reactivity.

Besides the shim rods there are four automatic regulation rods located in the reflector. Their position is changed automatically by the servo-motors activated by the ionisation chambers. If the chain reaction increases the automatic regulation rods go down, and if it falls off they rise. One pair of rods works at a time, while the other pair is in reserve. These regulators maintain the chain reaction at prescribed level to within 3 per cent accuracy. Finally there are two safety rods with servo-motors installed directly over the reactor's upper shield, to ensure prompt action. In case of an emergency these rods fall freely into the active zone of the reactor and thereby stop the chain reaction. In all there are twelve different emergency signals. The most important of them are: signals of 20 per cent rise above the prescribed power level, a signal of a too rapid increase of the chain reaction, a signal of the shut-off of electric current to the main circulation pumps, signals of changes in the flow and temperature of the water in the fuel channels.

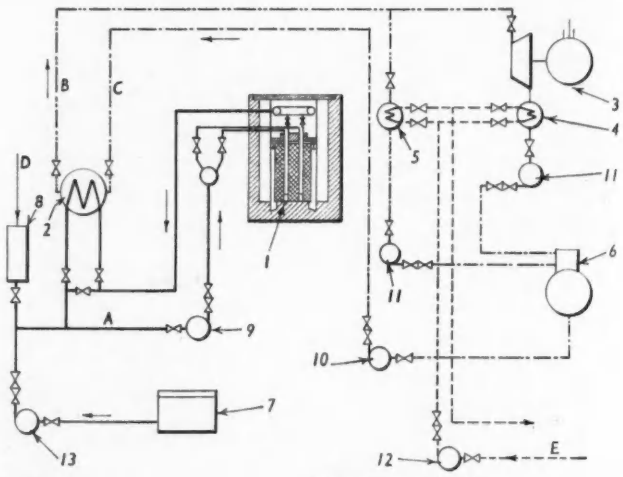
The reactor has a number of devices for physical investigations and tests of materials.

Biological shielding is ensured by a side water shield 100cm thick and a concrete wall 300cm thick. In the upper part of the reactor biological shielding is ensured by intensification of the graphite reflector, by the upper steel cover of the apparatus and by a cast iron plate. The shielding attenuates the fast neutrons, escaped from the reflector, the gamma radiation from the radioactive fragments, and, chiefly, from the thermal neutron capture in the iron of the construction. Since the shield is only approximately calculated special attention in designing the reactor was devoted to avoiding any direction for channelling of neutrons or gamma rays, such as that forming a small angle with the reactor jacket



1. Graphite brickwork
2. Lower plate
3. Upper plate
4. Fuel channel
5. Safety rod channel
6. Automatic control rod
7. Ionisation chamber
8. Side shielding (water)
9. and 10. Cooling circuits
11. Distribution (inlet) header
12. Outlet header
13. Top shielding (cast iron)

Fig. 7—5000kW Russian atomic power station reactor



1. Reactor
2. Steam generator
3. Turbo-generator
4. Turbine condenser
5. Starting condenser
6. Deaerator
7. Supplementary water tank
8. Volume compensator
9. Primary circuit circulation pump
10. Secondary circuit feed pump
11. Condensate pumps
12. Cooling water pump
13. Feed pump of the primary circuit

(*a*) Primary circuit water (100 atmospheres)
(*b*) Steam (12·5 atmospheres)
(*c*) Secondary circuit condensate
(*d*) Compressed air
(*e*) Cooling water

Fig. 8—Technological flow-sheet of the 5000kW Russian atomic power station

Fast neutron inelastic scattering at a big angle in the steel jacket of the reactor caused an almost vertical neutron flux. An additional concrete shield was set up in the way of this flux.

Technological Flow Sheet of the Atomic Power Station

As has already been mentioned, the most characteristic feature of the station scheme is the two-circuit system. The heat transfer agent is water, which circulates in the primary circuit under high pressure. This water transfers the heat from the reactor to the water of the second circuit. In the steam generators the water is converted into steam, which goes to the turbine. The entire primary circuit is made of stainless steel and is situated behind the so-called biological shielding.

The water of the primary circuit is heated in the reactor channels to a temperature of 260 deg. to 270 deg. Cent. and passes to the steam generators from the header (Fig. 8). There are eight such steam generators coupled in pairs in the shielded boxes. At peak power output three pairs of steam generators are in operation and the fourth pair is in reserve. Each steam generator consists of a water heater, a water evaporator and a steam superheater. The water of the primary and secondary circuits in the steam generators moves according to the counter-current principle.

The water of the primary circuit leaves the steam generators at a temperature of about 190 deg. Cent. and enters the inlet pipe of the main circulation pumps. There are four such pumps. Three are in operation at peak power output, ensuring water consumption of about 300 tons per hour; the fourth pump is in reserve.

There are special feed pumps for adding fresh water to the primary circuit. These pumps, with the aid of an automatic device, feed the water to seals of the main circulation pumps in such a way that the pressure of this water is always 0·5 atmosphere above the water pressure in the pump. This ensures a hydraulic seal which prevents the radioactive water in the main pumps from penetrating along the shaft.

It should be noted that as the water of the primary circuit moves away from the reactor its activity gradually falls. The activity of the water coming out of the reactor is due to oxygen activity (0·2 curie/litre) with a short decay period (seven seconds), whereas at the inlet of the reactor the activity of the water (2×10^{-5}) curie/litre) is due basically to activity of impurities.

To ensure compensation for changes in water volume during heating or cooling and to maintain for a certain period of time the pressure in the circuit in the case of a leakage, the arrangement is supplied with volume compensators, which are circular tanks connected with cylinders of compressed gas. A change in the volume of water in the primary circuit is compensated by either a fall or rise in water level in the volume compensators. The level reading is shown at the central control panel and is connected with safety rods.

Along the primary circuit line, on the by-pass, there are contact units for burning the explosive mixture which may arise through water decomposition due to neutron radiation. From the pressure line of the main pumps, the water enters the input collector of the apparatus, from which it is fed to the apparatus channels.

The water of the secondary circuit might become radioactive only as a result of mechanical mixing with the water of the primary circuit, for example, as a result of fissures in the tubes of the steam generators. However, this is highly improbable. Therefore, the equipment of the secondary circuit is conventional.

The water of the secondary circuit (the condensate) is fed by feed pumps to the heater of the steam generator ; it then enters the evaporator, in which the level is maintained constant by a special automatic device ; from the evaporator the steam enters the steam superheater. At peak power output of the station, the three operating groups of steam generators produce 40 tons of steam per hour at a pressure of 12·5 atmospheres and at a temperature of 255 deg. to 260 deg. Cent. This steam is supplied by the steam main to the turbo-generators. From the turbine condenser the water returns to the steam generators.

The station is provided with various electrical equipment, including a storage battery capable of feeding the electric motors of the main circulation pumps at low speed for several hours, which might be needed in an emergency (shutting-off the electric supply). The sole purpose of the equipment is to ensure a reliable source of electricity for the control instruments of the reactor and the main circulation pumps. A slight circulation of water in the reactor is needed even when the reaction is stopped, to remove heat due to decay of long-lived radioactive fission products.

All the station equipment is controlled from a central panel. The central control panel gives the following important readings : the position of the shim and control rods, the temperature of the water at channel outlet, water consumption in the primary circuit and water pressure, the power of the reactor, the quantity and quality of the steam produced, &c.

For safeguarding personnel from irradiation all rooms in the station are equipped with ionisation chambers for measuring gamma radiation and with air-intake lines for controlling the radioactivity of the air. In case the activity of gamma radiation or the activity of the air in any room is above normal, the man on duty at the central dosimetric panel is warned by a light and sound signal. This same signal is also given in the room where the activity has exceeded the normal level. All rooms at the station are well-ventilated and the air escapes through a high chimney. When the station is working normally, a slight source of radioactivity is the activity acquired by the argon of the air near the reactor. Radioactive water (when the water is let out of the primary circuit) is discharged to storage tanks, where its activity is reduced to the safety level by dilution and by decay.

Operational Experience

Since the atomic power station was started up on June 27, 1954, it has been tested in various operation conditions and has produced about 15,000,000kWh of electric energy. During operation of the station there has not been a single case of the fuel elements failing. This proves that the heat-transfer from the uranium elements to the water proceeds regularly without disturbances, and that the stainless steel selected for the tubes is a reliable material for work in the active zone of the reactor.

In view of the changes that graphite undergoes in a neutron field, it might have been feared that the holes in the graphite brickwork would become clogged with fuel elements. Experience in channel replacement showed that the fuel channels were easily removable. The temperature of the graphite proved to be above the rated temperature and at the hottest points reached 650 deg. to 700 deg. Cent.

Water flow through the fuel channels of the reactor was stable during operation. It is possible to reduce the spread of water outlet temperatures in the channels to ±7 deg. Cent. by controlling the water flow and equalising the neutron density along the radius of the apparatus.

Once the temperature and steam pressure are fixed the operation is characterised by a high degree of stability and the parameters may be maintained without requiring attention from the personnel of the station. The automatic control system and the breakdown protection system of the reactor worked without a mishap.

Start-up of the reactor from zero to the rated power takes approximately half-an-hour and is the most important operation, especially when the reactivity of the reactor is not precisely known. At present, work is proceeding on an automatic start-up project.

Unloading of the uranium fuel elements from the reactor is done by sections with a view to economising atomic fuel. The reactor is simultaneously loaded up with fresh heat-generating elements and the less burnt-up periphery elements are moved to the centre of the apparatus. This resulted in extending the operation period of the fuel elements and increased the burning depth of U235 to 20 per cent. The elements are replaced once in two months, requiring two to three days.

The main technological equipment of the station (main circulation pumps, booster pumps, steam generators, volume compensators, &c.) worked without failure. This is due, to a considerable extent, to the fact that during installation of the high-pressure pipe-lines, great attention was paid to the quality of welding. It should be noted that the total number of welded joints is several thousand.

High purity of the water of the primary circuit is necessary for successful operation of the reactor. Bi-distillate, with which the primary circuit was filled, has a dry residue of less than 1mg per litre. In the primary circuit, the content of dry residue is maintained at a level of 3mg per litre by constant removal of the primary circuit water and by adding up to 300 litres per hour of fresh bi-distillate. An increase in the dry residue is probably caused by washing away of copper gaskets and asbestos-graphite seals in the valves. Experience shows that the presence of this residue in the primary circuit does not lead to the formation of scales in the fuel channels to the extent of influencing heat transfer. Nevertheless, the station personnel consider desirable a further reduction of impurities in the water of the primary circuit. This would also make unnecessary the constant removal of water from the primary circuit.

Preliminary experiments† established the fact that at the temperature and pressure most common in the primary circuit, we find the reverse process of ion recombination that practically eliminates the formation of a detonating mixture in the water. This conclusion was completely confirmed during operation and made it possible to dispense with a contact apparatus for burning the detonating mixture.

The equipment of the secondary circuit is conventional type. But it was important to know how flexible the control of the whole scheme of the station was. At first, there was a little uncertainty in the controllability of the whole reactor—steam generator—turbine set-up, especially in transition operation conditions. No study was made of the start-up system of the turbine, permissible heating-up speeds of the steam generators, and speeds of steam pressure rise. As an example, mention may be made of hydraulic shocks that occurred in the steam generators when they were heated during the first start-up times. It later became clear that this was due to steam generation in the water heater. It was due to an excess heating speed and to low steam pressure in the steam generator.

A study of start-up conditions established the fact that start-up from a cold state, for example, after repairs, may be carried out in 1·5 to two hours, and the steam in the first period is delivered to the start-up condenser. After operation parameters have been attained it is fed to the turbine.

The automatic set-up of steam generator control is so stable in operation that the steam parameters are quite constant. As a result, the turbo-generator is absolutely stable in operation. Station operation conditions were studied in the case of various loads of the turbo-generators. The station was also tested on a heating regimen for the heating of building. The station was entirely stable in all conditions. The station personnel succeeded in switching over to the reserve steam generators and circulation pumps without any loss in the power of the turbo-generator, which is very important for ensuring normal operation of the station. The outlay on repair work conducted during the year was small, since it consisted mostly in examination, revision of equipment and various slight repairs.

During operation of the station, a detailed study was made of the efficiency of the designed biological protection. It turned out that the gamma radiation intensity in the main hall, at nominal reactor power, did not exceed 0·1mr per second, which is considerably less than the biological tolerance dose. When the apparatus is being unloaded the protection walls of the hall safeguard completely work in the surrounding rooms. Protection of the rooms of the steam generators, the pumps and pipelines of the primary circuit likewise safeguard the service rooms from radiation. For a limited period of time one may also enter the halls where this equipment is located (radiation does not exceed 6mr per second). Gas activity in the main hall of the station and in the other rooms is likewise not observed, which points to a satisfactory system of exhaust ventilation. The activity of the gas passing into the ventilation funnel was due basically to the activity of the argon of the air. Measurements show that the selected height of the ventilation pipe is sufficient insurance of safe conditions for the surrounding population as was provided for in the project. The activity of the water drained out of the primary circuit is 10^{-5} curie per litre as to Na and Mn. After its retention in storage tanks and after dilution with pure technical water, the activity of the drained water is easily brought down to the necessary biological level. In the case of breakdown in the channels, the presence of intermediate reservoirs excludes the possibility of fission fragment activity getting into the water.

Operation experience of the station showed that the system of local and central warning signalisation of elevated gamma and gas activity works without a hitch. During the time the station has been operating there has not been a single case of over-irradiation of personnel. Each worker at the station has control dosimetric photo plate holders and undergoes periodical medical examination. No harmful influence of the work of the station on the health of the workers has been observed. It should be noted that the most important means of combatting irradiation of the workers is strict discipline in observance of operation and safety regulations.

As general conclusion of a year's experience in operating the station is that an atomic electric power station having as its source of energy an atomic reactor similar to the one described above will be extremely stable and reliable in operation.

† P. I. Dolin, B. V. Ershler, "Radiolysis of Water in the Presence of H_2 and O_2 Under the Action of Reactor Irradiation, Fission Fragments and X-Rays," paper at Geneva Conference on the Peaceful Uses of Atomic Energy, 1955.

LETTERS AND LITERATURE

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

GEOPHYSICAL PROSPECTING

SIR,—As to the efficiency of the "Wünschelrute," or divining rod, for prospecting on minerals, I have neither knowledge nor experience. I only know that Dr. Brüche, a very well-known German physicist of some standing in the world, has published an extensive essay concerning it and that he would not give judgment. He leaves the question open, perhaps remembering his Shakespeare (there are more things in Heaven and Earth than our scientists are aware of). As to the use of the diviners' rod for prospecting for water, I once was (as I am always in such things) very sceptical. But in 1916, in Northern France, as we were searching for the best location for a well in a wood (for the watering point on a railway line) an old-timer "Rutengänger" of Western Africa, showed to me in a short time the most favourable site. I tried the location myself: the rod would not work. Then this man took my left hand, I his right, and, the rod between his left and my right hand, went as twins; and now the rod worked most energetically, so that I got a blue welt on the little finger of my right hand that tried to impede the inclination of the rod. From then on, for several years, I could play the water diviner, but I lost this faculty gradually, like a piece of iron that has been magnetised only temporarily by a permanent magnet.

A few weeks ago a well-builder who has to construct a 15m well on my land in the wood used a hazel twig again to locate the most apt point and got quite clear reactions (not I !). Now in the next month he will have to justify his findings.

ED. A. PFEIFFER-RINGENKUHL

Munchen,
August 12th.

Literature

Coal : Its Formation and Composition. By WILFRED FRANCIS. London : Edward Arnold (Publishers), Ltd., 41, Maddox Street, W.1. Price 84s.

A SIGNIFICANT feature of the times is the increasing interest shown by technologists in the background of their particular subjects and how they link up one with another and finally fit into the whole matrix of knowledge. This may be stimulated by the ever closer dependence of one subject on another for technical aid, but it will have wider influence. Thus the most determinedly practical of modern technologists must possess more than nodding acquaintance with the source and origin of the materials he studies. This applies to those concerned with our economically most valuable and in its composition most complex mineral—coal. The present book by Dr. W. Francis will therefore attract much wider attention and interest than is suggested by the author's prefatory note that it is "intended to help serious students of fuel technology and coal chemistry." The author has made a lifetime's study of the nature and origin of coal and in this book he summarises all available knowledge of the subject gained from his own researches and those of other workers at home and abroad.

Dr. Francis began his studies over thirty years ago under the late Professor R. V. Wheeler, of Sheffield University, who had established there a department of fuel technology which was the first of its kind in this country. Subsequently he has had extensive experience outside the laboratory and has taken part in the post-war surveys of the coal resources of Pakistan, Queensland, Victoria and Nigeria, carried out under the surveillance of Powell Duffryn Technical Services, Ltd. He is therefore extremely well qualified as author of this book, and this is shown by his comprehensive grasp of detail and principle alike, and by the wide field covered in his selection of material from the works of authorities in Europe and America referring to coals of all ranks and from every source in the world.

The origin of coal and the mode of its accumulation in the various forms we know are traced by selections made from many sources of information concerning the geological, geographical, climatic, chemical and biological factors involved. Two long opening chapters deal with the coal-forming plants of the primæval swamp and forests and their chemical composition. A fascinating account is given of the way in which the pollen grains, fungi and spores found in certain coals are used as tracers to establish the species of the original plants or trees which flourished many million years ago, and how they are used in the correlation of coal seams in different areas or fields. The subsequent transformation of the debris by chemical and biological agents is traced. The several processes involved in the decay of the different parts and substances of the original plants are discussed, and the influence of various environments on those processes. Particular attention is given to the influence of bacteria and of fungi on the formation of humic acid, as also the important part which that plays in the decomposition of plant debris, and its transformation into carbonaceous materials.

Here, as elsewhere in the book, Dr. Francis describes the more widely accepted theories in full, and mentions any other theories of special merit. It is vastly interesting to follow the evidence he uses to explain why coals of several geological eras are found in most coalfields ; and why they are themselves relatively small areas, often lying at the edges of the great land masses that have persisted throughout the ages, in which climatic and geographical conditions have permitted the growth of the plants and the accumulation of their debris either *in situ* or by sedimentation in lakes, estuaries and deltas.

The greater part of the book, however, is devoted to the study of mature coals, such as we have in this country. He deals with their composition, structure, petrology, classification, and with the terminology of the subject, including a definition of rank. The composition of mature coals is treated very thoroughly in one chapter, and in subsequent chapters special attention is given to the minerals or inorganic constituents which so greatly influence the use and value of any coal, e.g. pyrites, calcite, gypsum, &c.; and to the physical factors affecting their character and utilisation. Various systems of classification which have been proposed from time to time and adopted more or less extensively are described and discussed. They include those of Regnault, Seyler, Grout and Ralston, and Mott, in addition to those used by the D.S.I.R. and the A.S.T.M. The author then presents at considerable length the system which he has himself developed, and describes as a rational system, in order to differentiate between coals of the same rank but of different type. Much of the work is concerned with the chemistry of the subject as elucidated by researches carried out very largely within the present century, but some few of them dating back to about 1800. Excellent lists of references are given at the end of each chapter.

Modern methods of coal analysis are treated very fully in an appendix to the book. The techniques employed in the course of testing and research both to prepare specimens and to carry out their examination or analysis are given in minutest detail.

Dr. Francis uses some 200 microphotographs to illustrate the text, and they are selected from the collections of many research workers with reference to specimens from every principal source. The author makes full acknowledgment wherever he borrows material, and pays special tribute to the work and inspiration of his old teacher, Professor Wheeler.

The book is an indispensable work of reference to all students of the subject, for use during their studies and in later years, and is likely to become a classic in this field.

Industrial Dust. By P. DRINKER and T. HATCH. London : McGraw-Hill Publishing Company, Ltd., McGraw-Hill House, 95, Farringdon Street, E.C.4. Price 71s. 6d.

AN authoritative knowledge of dust technology is rapidly becoming more important throughout industry ; in fact, the ill-effects of dust pollution are experienced by the whole community. The industrialist, however, is primarily concerned, not only as the health of his workers is at stake, but also as uncontrolled dust may well spoil his product and perhaps represent direct financial loss if the dust has intrinsic value. It is gratifying, therefore, to find a general treatise on the subject, based on the obviously exceptional personal knowledge of the authors, which is eminently readable and represents an accurate cross section of the problem.

Probably it is true to say that *Industrial Dust* is one of the basic reference works, both in its own right and for its bibliography of no less than 458 references on the subject ; to the reviewer's knowledge, no wider index exists. Furthermore, it is refreshing to find in an American publication a completely objective approach, with full credit given to workers and governments overseas. This is typified in the chapter "The Effects of Dust and Fumes on Man," where appears the sentence "... but we still are a bit envious of the tidy way in which the British assemble their industrial data on morbidity and mortality."

Aspects of the subject matter covered by the authors may be roughly classified as follows :—

(*a*) Properties of dust.

(*b*) Physiological effects of dust on man and control methods.

(*c*) Estimation of dustiness and methods of analysis.

(*d*) Control of dust in industry in formation

and handling, and personal protection for the operative.

The adequate manner in which the subject is covered in what is, after all, a general treatise, makes comment difficult. It is a measure of the authors' thoroughness that the reviewer is forced on to specialised knowledge in an effort to provide material for constructive criticism.

In this spirit, therefore, one is disappointed at the absence of direct reference to recent advances in filtration technique, although for the careful reader the clue to these appears in the chapters dealing with filtration and respirators. Specifically, the electrostatic effects, which are believed to assist most gas filtration processes to some degree, have been harnessed in several designs by the use of suitable materials. Such filters rely predominantly on electrostatic attraction for their dust-arresting properties. Then, again, it has proved possible to combine the dust-arresting or collection properties of coarse and fine fibrous media by a uniform dispersal of the fine fibres throughout a matrix of the coarser fibres. The filters evolved, comparatively recently, in this manner show remarkable efficiency/pressure-loss qualities. Added to this, the extremely valuable information in the chapter on " Electrical Precipitation " tends to emphasise the undoubted utility of these plants while dealing very scantily with shortcomings ; here, again, the information is available for the intelligent reader to form a very fair opinion of the pros and cons for a given purpose.

This reviewer is somewhat diffident at raising the question of " smog," which is more than worthy of a volume on its own and has, in fact, produced several. Nevertheless, on consideration, he feels that the subject is sufficiently closely allied to " industrial dust " to warrant more than inferred reference in this particular volume. The connection between " smog " and process effluents is ever more closely being established, and it is to the industrialist that one must look for a major contribution towards future relief. Discharge of dust to atmosphere in city areas is being discouraged by legislation, so that the use of electric precipitators is becoming widespread in heavy industry. However, it is stated that certan precipitators produce ozone and oxides of nitrogen, so forbidding recirculation of air in enclosed spaces ; what is the position when these plants are installed in areas such as Los Angeles, where the smog problem is notorious, and where ozone and oxides of nitrogen are suspect as potentially harmful products ?

One might continue thus in reviewing any book as detail criticism is always possible. But the danger is that by so doing an erroneous impression may be created of the value of the work as a whole. Lest this impression should have been inadvertently given, the reviewer hastens to counter it with the statement that *Industrial Dust* is one of the three or four books which will be constantly at his elbow for reference. All in all, an excellent guide to a highly complex subject, well worthy of study by anyone responsible for operating dusty processes, or, for that matter, by anyone concerned with dust and that includes most of us !

Electric Railway Engineering. By T. FERGUSON. London : Macdonald and Evans Ltd., 8, John Street, Bedford Row, W.C.1. Price 57s. 6d.

AT a time when a large scale changeover from steam to electric and diesel-electric traction on British Railways has been announced this book should be particularly welcome. The author, formerly Chief Engineer, Electric Railway Project Department of the Metropolitan Vickers Electrical Company, Ltd., assumes on the part of the reader a basic knowledge of traction, of electric motors and of control in general, and he proceeds to analyse a number of specific problems connected with the practical application of electric traction to railways. It should be said at the outset that he deals extensively with diesel-electric and gas-turbine-electric locomotives, as well as with straight " electrics."

A great deal of Mr. Ferguson's book concerns the application of the known characteristics of the motive power to the establishment of train services. The determining of time-speed curves ; the power demand resulting from any particular service, having regard to gradients, frequency of stops and so on. One of his longest chapters is that dealing with braking on electrified railways. Detailed references are made to the rheostatic, and regenerative systems, though his references to ordinary friction braking are confined to the theory of deceleration based on the frictional characteristics between wheel and block during retardation first established during Captain Galton's classic experiments of 1878.

Further chapters deal with train resistance, weight transferences on locomotive axles, auxiliary machines for locomotives and motor coaches, and transmission to mercury arc sub-stations ; but one of the most interesting, and perhaps controversial sections of the book is the group of chapters devoted to comparisons between electric, diesel-electric, and gas-turbine-electric locomotives. With the experimental 3000 h.p. gas turbine locomotive No. 18100 (Western Region) as a basis comparison is not to the advantage of the diesel-electrics, on prime cost, weight factor, or estimated running costs. Such comparisons, however, no doubt look forward to the time when both forms of motive power are well established. So far as British Railways are concerned neither type has so far been conspicuously successful, as many minor faults have seriously affected the availability.

A very detailed chapter contains a fully worked out example of railway electrification, taking a route 200 miles long with varying intermediate gradients. While no doubt the actual example quoted is intended to indicate the method of analysis rather than the conditions likely to be met with in practice one feels that the author might have been a little more realistic in the selection of his data. A 200-mile stretch with no more than nine passenger and nine freight trains in each direction in the twenty-four hours, and only one of the eighteen trains in each direction making an intermediate stop hardly suggests the need for electrification at all, particularly with schedules so evenly spaced as to suggest an operating man's dream of Heaven ! The operating problem to-day is that of dovetailing in an increasingly intense service of trains, with fast express passenger and freight trains carrying " block " loads interspersed with those providing intermediate facilities. From the very simple and ideal service he has conceived, the author determines the train performance, the number of locomotives required, spacing of sub-stations, having regard to losses between the supply source and the trains, and the transmission lines to the sub-stations. While on the subject of transmission it is interesting to note that in comparing the different systems of electric traction he does not consider that the French experiments with a supply at commercial frequency have been carried far enough for any definite conclusions to be made. He feels that a traction load is likely to be too severe and too fluctuating to be taken direct from a national " grid " without disturbance to other users.

Although, as will be gathered, Mr. Ferguson's book includes matter that cannot be other than controversial, in embodying a vast amount of data that is the fruit of his long experience in the subject it constitutes a text book of profound interest and value to all concerned in the electrification of railways.

Noise-Reduction Manual. By P. H. GEIGER. London : Geoffrey Cumberlege, Amen House, Warwick Square, E.C.4. Price 40s.

ORIGINALLY prepared under the auspices of the United States Office of Naval Research, this volume is consistently practical and useful. An adequate treatment of fundamentals is given : wherever possible a formula is supplemented by a graph for rapid computation. Considerable space is devoted to a discussion of the units of measurement used, with particular reference to their correlation with physiological effects. Separate chapters are given to sound insulation and vibration damping, the limitations of the latter being made clear. Always in this work emphasis is laid on corrective treatment, and it is never suggested that freedom from vibration and resonance is a practicable design requirement. The descriptions of methods used and results obtained in such work, particularly in difficult conditions with variable speed machinery, are attractive reading and bear out the author's proposition that there is no routine analysis in a noise reduction essay.

The book is reproduced from typescript but has a complete and well-divided table of contents and a comprehensive index : it should prove of real value to those who have not had specialist training in this field. The one important aspect of noise reduction which is not mentioned is the silencing of internal combustion exhausts.

Centrifugal and Other Rotodynamic Pumps. By Herbert Addison, O.B.E., M.Sc., M.I.C.E., M.I.Mech.E. Second edition. London: Chapman and Hall, Ltd., 37, Essex Street, W.C.2. Price 50s.

—The first edition of this work was published in 1948, and the second preserves the original presentation with revisions to correspond to recent advances in design and construction. The bibliography has been revised : it includes references from Australian, British, Egyptian, French, German, Italian, Swiss and United States sources, and is arranged to correspond with the text, with divisions for principles, design and construction, performance and installation and operation. The index also indicates in which part any reference lies.

Books Received

L'Equilibre des Corps Deformables. By G. Colonnetti. Paris : Dunod, 92, Rue Bonaparte (vi), Paris. Price 1·680F.

Dynamics of Machinery. By A. R. Holowenko. London : Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 60s.

Introduction to Electronic Analogue Computers. By C. A. A. Wass. London : Pergamon Press, Ltd., 4-5, Fitzroy Square, S.W.1. Price 40s.

A Steam Locomotive for O'Gauge. By N. Dewhurst. London : Percival Marshall and Co., Ltd., 23, Great Queen Street, London, W.C.2. Price 5s.

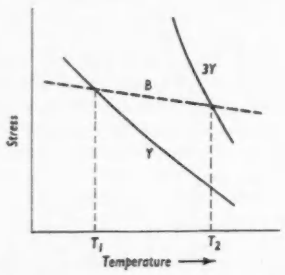
Colliery Year Book and Coal Trades Directory, 1955. 33rd Edition. London : The Louis Cassier Co., Ltd., Dorset House, Stamford Street, S.E.1. Price 30s.

Civil Engineering Design. Fourth edition. By T. W. Barber. Revised by Rolt Hammond. London : The Technical Press, Ltd., 1, Justice Walk, Lawrence Street, London, S.W.3. Price 25s.

Metallurgical Topics

Brittle Failure of Steel Structures

THE history of brittle failures in steel structures and factors of importance in this class of accident, viz. low temperatures, the presence of a notch, however caused, introducing triaxial stress, and (less essentially) a high rate of strain, were discussed in two articles by M. E. Shank in *Metal Progress*, September and October, 1954. Professor Shank has now summed up in a final article* on theory, practice and future prospects.



Yield strength Y, brittle strength B, flow stress in the presence of a notch $3Y$.
Above T_2 material breaks with a ductile fracture; below T with a brittle fracture.
The region between T_2 and T_1 is the transition range.

Fig. 1—Transition temperature in a notch-brittle material

The general explanation of brittle fracture is in accordance with the diagram shown in Fig. 1, which indicates the change with temperature of the brittle strength B, the yield strength Y, and the flow stress in the presence of a notch, which is three times the yield strength. It is experimentally known that the yield strength rises with decreasing temperature. It is, as Professor Shank states, assumed that the brittle strength will also rise with decreasing temperature, but not at so steep a gradient. Before the rest of the article is summarised, some points arising out of this section may be considered.

CLEAVAGE STRENGTH OF STEEL

The assumption that the brittle strength of steel increases with fall in temperature is borne out by the results of tensile tests made at low temperatures by A. S. Eldin and S. C. Collins†

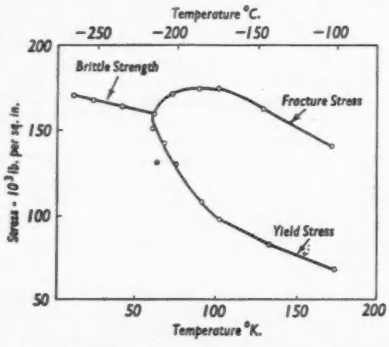


Fig. 2—Tensile tests on 0·2 per cent carbon steel, showing evidence of a brittle strength curve (Eldin and Collins)

on a 0·2 per cent carbon steel with test pieces of 0·32in diameter. Their results are shown in Fig. 2. Below 61·5 deg. absolute no reduction of area occurred and the stress to fracture increased with further fall in temperature. Above that temperature, yielding took place with reduction of area before fracture. On the other hand, some recent low-temperature tests indicate a decrease in the "nominal cleavage strength" of steel as the temperature is reduced. This apparent discrepancy may possibly be due to the fact that the tests now to be referred to were in the nature of tear tests rather than tests made under uniaxial tension.

Experimental work on the following lines has been described by Tore Norén.‡ A brittle alloy was welded on the edge of flat tensile test pieces of several soft steels. On exposing such test pieces to an increasing tensile stress, fresh cracks were continuously formed in the brittle surface layers. At a certain critical stress one of the cracks formed continued into the steel, and a brittle fracture was obtained. It was shown that the "nominal cleavage strength" (defined as the highest tensile stress a steel could maintain without fracture in the presence of a crack) was a characteristic property of the steel. The

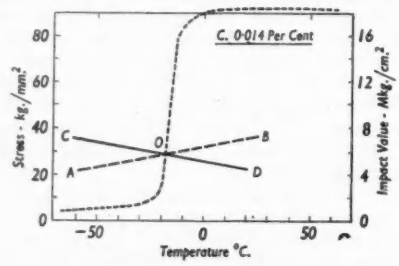


Fig. 3—"Nominal cleavage strength" (*AB*), yield strength (*CD*) and Charpy V-notch impact value of a 0·014 per cent carbon steel (Tore Noren)

nominal cleavage strength decreased continuously as the temperature of testing was lowered, while the conventional yield point increased continuously with decreasing temperature.

The point of intersection of these two curves would appear to be a transition temperature for the steel, and might be defined as the temperature above which deformation can occur in a large volume of material despite the presence of a crack, but below which only local plastic deformation, immediately in front of the crack, is possible. Examples are given in Figs. 3 and 4

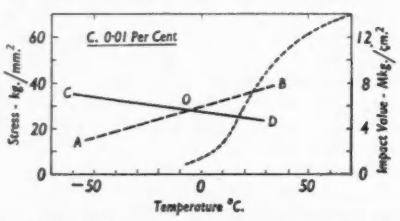


Fig. 4—"Nominal cleavage strength" (*AB*), yield strength (*CD*) and Charpy V-notch impact value of a 0·10 per cent carbon steel (Tore Noren)

The curves *AB* represent the nominal cleavage strength obtained as described above on the edge-welded specimen. The curve *CD* represents the yield point, the portion *CO* being obtained with conventional test pieces and *OD* from tests on edge-welded specimens. A certain correlation with Charpy V-notch impact tests was found, and is indicated in the figures. That shown in Fig. 3 was exceptional and applied only to the relatively pure iron specimen. Fig. 4 is more typical of results shown by the other steels.

FUTURE PRACTICE

To revert to Professor Shank's paper, in which, after summarising theories of brittle failure, he deals with present and future practice. He suggests that in order to prevent brittle failure with certainty the first alternative would be to make use of such austenitic steels as are immune to brittleness at all temperatures. On account of the cost, and also because of their low yield strength, this would only be possible in special cases—for example, in equipment working at very low temperatures, liquid air containers, &c. The second alternative is the use of good quality ferritic material with the lowest possible transition temperature of ductile to brittle fracture, fabricated in such a way as to ensure complete absence of flaws and stress-raising defects.

Much discussion has centred on the proposal to use aluminium-killed or thoroughly deoxidised steel. It is well known that for steels that are generally similar a fully killed steel will have a lower transition temperature than a semi-killed steel. Likewise, a semi-killed steel has a lower transition temperature than a rimming steel. These distinctions are not clear cut; there is some overlap. However, the use of rimming steel may have contributed to some brittle failures.

The various tests for notch brittleness are consistent within themselves in that they generally rate a given group of materials in relatively the same order. None is absolute; their numerical results in foot-pounds of energy absorbed cannot be used directly in design nor applied directly to the behaviour of full-size structures. Tests for notch-brittleness are only of value when correlated with experience derived from the behaviour of structures in service. The requirement of a minimum notched-bar impact value at a specified low temperature (for example, the A.S.T.M. standard, which requires a minimum Charpy V-notch impact value of 15ft-lb at −20 deg. Fah. (−29 deg. Cent.), or at some lower temperature) is as good a guide to the relative immunity of a steel to brittle failure as is available at the present time.

There are structural steels which will give this impact value or higher figures down to −40 deg. Cent. From a number of steels of suitable strength, the fabricator is free to choose steels of different composition and steels subject to different deoxidation procedure. At the same time, in the construction of ships, bridges, pressure vessels, &c., both material and fabrication costs must be held at a reasonable level. It may, therefore, not always be possible to choose the steel showing the greatest immunity to brittle failure. As a consequence, Professor Shank points out, much of the burden for the prevention of brittle failure must be placed on good design which will eliminate stress concentration in the selected material, and on good workmanship which will ensure absence of flaws and other defects, coupled with rigid inspection, including X-ray examination of welds.

O.E.E.C. Report on Powder Metallurgy

THE Powder Metallurgy Mission, comprising twenty-eight members representing seven European countries, who visited America in 1953, has issued a final report.* It contains descriptions of the plant and operations that they were shown, comments on developments in the industry, and conclusions and recommendations based on what they had seen and heard. There were certain sections of the powder metal industry in America (for example, applications to tungsten, molybdenum, titanium and zirconium, and the production of certain engineering powders), which they were unable to examine in detail. In spite of this, the report contains a valuable assessment of American powder metal products of all kinds, and of their industrial importance. They are considered under four headings: electrical and magnetic materials; hard metals; tungsten wire production, cermets, titanium and zirconium; engineering powders and structural parts.

MAGNETIC MATERIALS

In the United States almost all radio cores are made from carbonyl iron powder, mostly of similar grades to those used in Europe, but new kinds of fine powder for very high frequency cores have recently been developed. The production of sintered magnets is described and the

* *Metal Progress*, June, 1955, page 111.

† *Journal Applied Physics*, 1951, Vol. 22, page 1296.

‡ *Jernkontorets Annaler*, 1955, No. 3, page 141.

* *Powder Metallurgy*, published by O.E.E.C., Paris; obtainable through H.M. Stationery Office.

magnetic properties of American products recorded. The high cost of the constituent powders and improvements in casting techniques, such as precision casting and shell moulding, have, however, limited the scope of sintered magnets to those weighing only a few grammes and required in large quantities. The use of ultra-fine powder for permanent magnet production is still in the experimental and development stage.

Since 1945 much development has taken place in the application of sintered mixed oxides of iron and of other metals for low-loss cores and for permanent magnets. These materials, generally known as ferrites, are made by methods closely akin to those used in powder metallurgy. The manufacture of low-loss ferrites in the United States is extensive and is described in the report at some length. The production of permanent magnet ferrites is less advanced. The first permanent magnet material made from oxides on a production scale in America was Vectolite, consisting of 30 per cent Fe_2O_3, 44 per cent Fe_3O_4 and 26 per cent Co_2O_3. This was prepared by pressing the mixed oxides to shape, lightly sintering to produce some mechanical bonding and magnetising by cooling in a magnetic field. The well-known barium ferrites, which are in large-scale production in Europe, had, at the time of the visit, only reached pilot scale production in the United States.

Apart from the applications of powder metallurgy in television and telecommunications, the use of iron powder products in connection with low frequency power supplies appeared to be increasing.

Hard Metals

The consumption of hard metals is enormously greater in the United States than in the United Kingdom. The very large automobile, aircraft, electrical and agricultural machinery industries consume large numbers of hard metal tools to achieve their high output. As a result the larger makers are able to introduce mass production methods in many of the hard metal tip and tool-making processes. The report contains an extensive review of the American cemented carbide tool industry and its products. Mechanically held carbide tools have some advantages over the usual brazed tips, and have achieved great popularity. They are primarily intended for use in certain kinds of automatic or semi-automatic machines.

At least two companies were manufacturing sintered chromium carbide. This was not intended to be used for cutting tools, but is found to be useful as a corrosion-resistant material in gauge blocks and in components subject to wear for use in the chemical industry.

The machining of hard metals offers great difficulty and three electro-erosive methods are described as well as one dependent on ultrasonic vibrations. The electro-erosive methods are the electrolytic, electro-arcing and electro-sparking. The ultrasonic process referred to ("Cavitron") was described in *Machinist*, September 26, 1953.

Cermets

During recent years the demand for materials possessing high strength at elevated temperatures has increased to a very great degree owing to the advent of the gas turbine. The range of properties demanded is so great that at present no material is entirely satisfactory in all respects. The search for a suitable material has spread from the iron, cobalt or nickel-chromium base alloys to substances of a less metallic nature and to ceramics. Cermets are a group of materials of an intermediate character, comprising refractory carbides, nitrides, borides, silicides or oxides, with or without a cementing metal. On account of their refractory character, powder metallurgical techniques are used in their fabrication. Titanium carbide base cermets appeared to be at the most advanced stage of development. Many of these suffered from the defect that their stress-rupture values decreased steadily with time at temperatures like 980 deg. Cent. This was overcome in such materials as Cermet 111-B (viz, titanium carbide 55·4, titanium boride 17·9, silicon 10·0, cobalt 16·7 per cent), but at the expense of reduced ductility and resistance to thermal shock. The chromium-alumina cermets (alumina 70, chromium 30 per cent) gave excellent resistance to oxidation and maintained high strength, particularly during long periods at elevated temperatures, but were deficient in ductility and thermal shock resistance. Molybdenum base alloys are not themselves resistant to oxidation, and at the time of the visit no satisfactory means of protecting the alloys from oxidation at high temperatures had been devised.

Although the emphasis throughout all this work was on the needs of gas turbine designers, the unique properties of many of the materials were being considered for use in chemical, electrical and mechanical engineering, when components have to operate at very high temperatures or are subjected to intense wear, oxidation or corrosion.

Structural Parts

Although the production of ferrous parts has only been a practical proposition since 1945, the present output is very great. The automobile industry has been the backbone of this development, each car now containing from forty to one hundred sintered parts, while second in importance is the home equipment industry (refrigerators, vacuum cleaners, &c.). Iron-copper mixtures are used for possibly 40 per cent of the ferrous parts made and, while the copper addition varied considerably, for the majority of applications 5 to 7 per cent of copper would appear to give optimum results. Infiltration of molten copper or copper alloy into the pores of presintered iron gives a compact possessing enhanced mechanical properties including ductility. The production of alloy steels by the use of high-alloy powders is receiving attention, but such products have not yet found any wide industrial application.

The output of non-ferrous parts in the United States is approximately 40 per cent of the total production. The majority of these are self-lubricating bronze bearings. These are usually oil impregnated, but incorporation of graphite, lead, or lead-base alloys is frequently employed. An aluminium oilite is also made for use in aircraft to prevent galvanic action between the bearing and housing.

Manufacturing Processes

Three chapters of the report are devoted to descriptions of pressing processes and equipment, furnaces, standardisation and quality control. To these are added two chapters and appendices of special interest to manufacturers of powder metallurgy products.

Though written primarily for the information of manufacturers and experts in powder metallurgy, the report will give engineering designers and others interested in the possible utilisation of powder metal products an insight into the recent developments of powder metallurgy in the United States.

High-Strength Steels

The limitations in treatment and manufacturing operations which are entailed by the introduction of very high tensile steel parts in aircraft construction were recently discussed by Mr. P. M. Mozley, chief metallurgist of the Lockheed Aircraft Corporation, in a paper summarised in *Metal Progress* for July, 1955, page 78. The use of steel having a tensile strength of 116 to 125 tons per square inch for landing gear struts of large aircraft has almost doubled the stresses which were permissible when similar parts were made from steels of 67 to 76 tons per square inch tensile strength.

It has, of course, been necessary to accept a correspondingly low elongation and impact energy figure, but this, though justified by experience, imposes serious limitations in manufacturing operations. The steel at present used at Lockheed is S.A.E. 4340, which contains :—

	Per cent		Per cent
Carbon	0·38–0·43	Manganese ...	0·60–0·80
Silicon...	0·20–0·35	Nickel	1·65–2·00
Sulphur	0·04 (max.)	Chromium ...	0·70–0·90
Phosphorus ...	0·04 (max.)	Molybdenum ...	0·20–0·30

The maximum section to which it is applied is not given. The steel is somewhat similar to En 24, of which the limiting ruling section for minimum tensile strength of 100 tons per square inch is 1½in. The best test results were obtained by a preliminary normalising at 870 deg. Cent. and austenitising at 800 deg. to 815 deg. Cent. for a longer time than usual rather than at a higher temperature, then oil quenching followed by tempering at a temperature between 200 deg. and 260 deg. Cent., according to the hardness of the steel in the quenched condition. Machining offers greater difficulty than with steels of lower strength, but could be effected at high speed with carbide tools. The amount of grinding permitted after heat-treatment is limited. The tempering temperatures are so low that stress relief by heating is not possible. Heating to 190 deg. Cent. is permissible but is not very effective, and the areas ground are shot-peened to improve the fatigue properties and to prevent cracking in subsequent cleaning or plating operations. The high-strength steels show an increased susceptibility to hydrogen embrittlement, but experience with plated specimens was conflicting. Some were ductile after baking at 190 deg. Cent.; others remained brittle after a long period at the same temperature. This difference in behaviour has so far not been tracked down to any particular variable in the cleaning or plating process. Test specimens are therefore always included in each load to be plated.

In general, the ratio of fatigue limit to ultimate tensile strength is the same for these steels as for those of lower tensile strength, but decarburisation may have a very detrimental effect. A little decarburisation is just as bad as deep decarburisation in its influence on the fatigue properties of steel treated to a high strength level. Damage to fatigue was about the same whether the depth of decarburisation was 0·003in or 0·030in. An endeavour to avoid decarburisation by control of furnace atmosphere may result in a slightly higher carbon content in the surface layer, but this also is undesirable. A carbon gradient at the surface should be avoided. It is regarded as safer to permit some unavoidable decarburisation and to shot-peen the part. There may be a requirement to machine certain critical areas after heat-treatment to ensure freedom from decarburisation. However, shot-peening is reported to be very effective in almost fully restoring the expectation of life of the parts.

Standardised conditions of manufacture are of the greatest importance as the only check on the strength of the finished part is a hardness determination. The hardness must fall within certain limits determined by direct measurements on the kind of steel used at the extremes of the range of permissible tensile strength.

The upper limit of tensile strength specified at Lockheed for steel 4340 is 125 tons per square inch, but Mr. Mozley regards this as only an intermediate stage. The demands of the engineer will be raised as aeroplane parts become larger and steels of higher strength become available. A tensile strength of 300,000 lb per square inch (134 tons per square inch) is given as the requirement of the immediate future.

Increasing Productivity with Welding.—The British Welding Research Association is arranging a number of meetings on increasing productivity by the use of welding, to be held at various centres throughout Great Britain. The first meeting is in Glasgow on Tuesday and Wednesday, September 20th and 21st, at the Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2. This meeting will be opened at 9.30 a.m. on Tuesday, September 20th, by Mr. Andrew Hood, the Lord Provost of Glasgow. Opening addresses will be given by Mr. F. E. Rogers, Chief of the Productivity and Technical Co-operation Division of the United States Operations Mission to the United Kingdom, and by a representative of the British Productivity Council. The following papers will be presented during the two days of the meetings : "Recent Developments in Welding Steels," by A. R. Muir, B.Sc.; "Recent Developments in Welding: Non-Ferrous Resistance Welding," by P. T. Houldcroft, B.Sc.; "Improving Quality and Reducing Costs by Resistance Welding," by J. E. Roberts, M.Eng., A.I.M.; "Recent Developments in Non-Destructive Testing," by H. L. Carson, B.Sc., A.Inst.P.; "A New Method of Designing Structures," by G. M. Moir, B.Sc., Ph.D., M.I.Struct.E., A.M.I.C.E.; and "What Can be Done to Reduce the Possibilities of Fatigue Failure and Brittle Fracture," by A. A. Wells, B.Sc.

Exhibition of Peaceful Uses of Atomic Energy at Geneva

No. IV—(*Continued from page 262, August 19th*)

U.S. "Swimming Pool" Reactor for Research

THE United States research reactor, which was shown in operation as a separate exhibit in the grounds of the Palais des Nations at Geneva, is known, colloquially, as a "swimming pool" reactor. It is a simple design, consisting, essentially, of an enriched U235 core enclosed in aluminium "sandwiches" and immersed in a pool of water which acts as coolant, moderator and radiation shield. It operates at a power level of 10kW nominal and 100kW maximum, and contains 3·6 kg of U235.

The pool of water in which the reactor is submerged is contained in a steel tank 10ft in diameter and 22ft deep, of which all but the top 4ft is buried in the ground. This tank contains about 13,000 gallons of ordinary water which has been demineralised by a mixed-bed ion-exchange process, yielding a purity approximating to that of distilled water. Above the top of the reactor core there is a depth of water of 16ft 6in, which provides enough shielding when the reactor is working at 10kW to reduce the radiation level at the water surface to about 0·5 mr per hour (which is about a quarter of the radiation intensity from the dial of a luminous wrist watch). The radioactivity produced in the water is small and is continouusly removed by recirculating the water from the pool through another ion exchange plant.

The core of the reactor consists of twenty-three fuel assemblies stacked vertically side-by-side in a compact group and mounted on an aluminium grid plate resting on the bottom of the tank. Three of the fuel assemblies contain holes designed to receive the control and safety rods. A special element is designed to hold a neutron source to simplify control of the reactor when it is being started.

Each fuel assembly consists of eighteen composite plates assembled in a parallel stack, the plates being spaced 0·117in apart and the sides being brazed into a pair of aluminium spacer plates. This arrangement gives a high surface-to-volume ratio to assist heat transfer to the water.

Each of the composite fuel plates making up the assembly consists of UO_2 particles (enriched to 20 per cent U235) uniformly embedded in a matrix of aluminium powder which in turn is completely enveloped in high-purity aluminium sheets. The central core, which is the fuel-bearing part of the composite plate, is made up of 54 per cent UO_2 and 46 per cent (by weight) of aluminium powder. The hot-rolling process used to sheath the core in aluminium yields a good metallurgical bond between the cladding layers and the core matrix and hermetically seals the latter. The core of the composite plate is 0·025in thick and the aluminium sheathing on each side is 0·0175in thick. Each standard eighteen-plate fuel assembly contains 967 grammes of UO_2 and 170 grammes of U235.

The fuel plate assemblies that accommodate the control and safety rods differ from the normal assemblies in that none of the central plates are removed to make room for the rod.

Three withdrawable vertical rods containing boron carbide control the neutron flux level of the reactor. The reactor is brought up to power by withdrawing the boron carbide rods. Withdrawal is effected through electric motor-driven rack and pinion mechanisms coupled to the rods themselves through electromagnets. Each electromagnet moves inside a guide tube to maintain correct alignment of the boron carbide rod. Rapid shutdown of the reactor is effected by switching off the electromagnet, whereupon the boron carbide rods fall by gravity into the reactor lattice and stop the reaction by reducing neutron multiplication; the electromagnetic coupling has the merit that it "fails to safety." Each rod has a piston shock absorber to protect it from damage and limit recoil.

The facilities and instrumentation provided on the control panel are probably more comprehensive than would normally be needed for a reactor of this size. Provision is made for fully automatic starting of the reaction and a simple servo mechanism for maintaining constant power is included. Electrically-operated indicators show by simulation the positions of the three control rods and limit switches restrict the travel of the rods. The withdrawal of the rods is independently variable, and the speed of operation is limited to allow a total start-up time of about seven minutes.

The safety control system of the reactor consists of three neutron-level safety channels, two counting-rate channels, one period channel and one linear channel, all of which operate through a servo-control mechanism. In this reactor the third safety channel constitutes an additional safeguard in that the radiation level is continuously measured in three places—the control room, the water demineralisation room and the environs of the reactor pool itself. If the radiation level at any of these places should become excessive (or if any of the instruments should fail) an audible alarm is given, the control rod motors are reversed, driving the rods into the reactor core, to stop the reaction. A separate instrument constantly samples the air in the reactor room and operates the alarm in the event of the air becoming contaminated.

Some of the typical uses of this simple and inexpensive research reactor were demonstrated in conjunction with the working exhibit. It can be used for studies in reactor design, nuclear physics and shielding, for examining the chemical effects of high-energy radiation, and for the production of millicurie quantities of radioactive isotopes.

Construction of the swimming pool reactor was started in March last at Oak Ridge National Laboratory and it was ready to be tested late in May. In the meantime a start had been made on the special building in the Palais des Nations, Geneva and by June 17th it was ready to house the reactor. The reactor was then flown from the United States and installed in its exhibition building in July, which allowed for a period of testing before the opening of the exhibition on August 8th.

Russian 5000kW Power Station

One of the exhibits that attracted considerable interest in the U.S.S.R. section of the exhibition at the Palais des Nations was a model of the 5000kW power station built by the U.S.S.R. Academy of Sciences.

The station, which has been generating electricity since June 27, 1954, makes use of heat from a pressurised, water-cooled thermal uranium-graphite reactor to generate steam which drives conventional turbo-alternator plant. By the use of primary and secondary heat transfer systems between the reactor and the steam generators, the possibility of radioactivity reaching the turbine room is reduced. The reactor consists of a core of 128 vertical fuel channels, each in the form of a long graphite cylinder containing thin-walled steel tubes carrying the primary circuit water. Inside these tubes are the uranium fuel elements which, in all, occupy a cylindrical space, 150cm in diameter and 170cm high, constituting the active zone of the reactor.

The 128 fuel channels are encased in graphite blocks which are sealed in a cylindrical steel jacket filled with helium or nitrogen. The reaction is controlled by eighteen boron carbide rods which can be moved vertically by means of servomotors, the positions of the rods being indicated on the central control panel. A view of the upper part of the reactor in operation, showing the shielding plate and safety-rod servomotors, is given in the illustration opposite.

Further details of the design and construction of the station, together with its operating experience were given in a paper by D. I. Blokhintsev and N. A. Nikolayev presented at the Geneva Conference on the Peaceful Uses of Atomic Energy. Abstracts from this paper are reproduced on pages 293 to 295 of this issue.

Another model in the U.S.S.R. display was built of transparent plastics to show the general arrangement of a heavy-water reactor designed for experimental work in nuclear physics. The nominal capacity of this reactor is given as 6500kW and the maximum capacity as 10,000kW, the average neutron flux density being $2·9 \times 10^{13}$ neutrons per square centimetre per second.

The reactor core is contained in a cylindrical aluminium tank (1·5m in diameter) and consists of aluminium tubes with fuel elements of enriched uranium. The tank is filled with heavy water in which the aluminium tubes are arranged in the form of a square lattice. Closed circuit circulation of the heavy water in the uranium fuel elements constitutes the primary cooling system. Water is pumped through a secondary cooling system to abstract the heat from the heavy water via a heat exchanger. The space above the level of the heavy water is filled with helium. The products of radiolysis of heavy water are drawn off and burned in a catalytic combustion chamber to form heavy water which can be returned to the reactor chamber.

Two control systems are installed: one maintains the power level constant to within 0·5 per cent; the other which is more accurate can be used for physical measurements, maintaining the power level to within 0·11 per cent.

Fabrication of Special Materials

The industrial development of atomic energy has created pressing demands for new materials with special properties to withstand high temperatures and the effects of intense irradiation. Some idea of the intensive work required to meet these demands was given in an interesting display of exhibits, at the Palais des Expositions, by Tube Investments, Ltd., The Adelphi, London, W.C.2. These exhibits showed some of the new materials that have been developed, with examples of components made from them and of the methods of fabrication required. The pace of progress in this specialised field can be assessed from the fact that it is only during the past three

The top shielding of the 5,000kW power reactor can be seen here. Projecting from the central part of the shield are the two servomotor drives for the control rods.

or four years that some of these metals have been made available in the pure state, in sufficient quantities to allow fabrication to be attempted.

The need for materials to withstand the high temperatures and the effects of neutron bombardment in reactor cores has led to a demand for materials such as niobium, vanadium, molybdenum and tantalum in the form of ductile tubes. Typical examples of this class of fabrication were exhibited.

Two other metals, zirconium and beryllium, are important, particularly in reactor core construction, because they have a low absorption cross section for thermal neutrons (that is to say, they absorb few of the neutrons in the reactor). Beryllium is also useful as moderator for slowing down the neutrons. Examples were shown of a few of the sizes of beryllium tube (ranging from 2½in in diameter and ⅛in wall thickness, to 1in in diameter and only 0·05in wall thickness), produced for the U.K. Atomic Energy Authority. The processes used for producing these tubes include direct extrusion from cast billets and from powder or flake. The metal, zirconium, was represented among the exhibits by a coil of zirconium tube made for the Atomic Energy Research Establishment, Harwell, and by a tube having a wall thickness of only 0·003in.

Uranium fuel elements in tubular form allow for improved heat extraction by flow of coolant along both inner and outer walls, and Tube Investments, Ltd., have developed methods of extrusion from powder and from a cast uranium billet. One of the exhibits showed a sample of tube hot drawn from a cast billet by Weldless Steel Tube Company, Ltd., using the push-bench process.

On the same stand there was an example of a bimetal tube consisting of an inner tube of uranium extruded directly with an outer sheath of zirconium, the metallic bond between the two tubes providing the thermal contact required for satisfactory heat extraction in a power-producing reactor. A uranium bar bonded with an outer sheath of zirconium was also shown.

Of the conventional materials used in atomic energy plants, Tube Investments, Ltd., has supplied quantities of stainless steel tube of various sizes, from 0·015in o.d. to 9·625in o.d., mainly in the form of seamless drawn tubing; but new forms have been developed for special purposes, such as Bourdon and capillary tubing for instrumentation. Thin-walled stainless steel tubing (down to 0·003in wall thickness) has been specially produced with a view to exploring the possibility of using stainless steel in reactor cores by first overcoming the disability that stainless steel readily absorbs neutrons.

Among the special products developed from conventional materials is a circumferentially finned mild steel tube in which the fins are rolled out of the tube wall. This method of construction should facilitate heat transfer, which is a specially important factor in the gas-cooled reactor.

Composite tubing has also been developed so that economic use can be made of the good mechanical or heat conducting properties of materials such as mild steel or copper tube by providing a corrosion-resistant lining to protect the outer sheath. For example, tubes of mild steel lined with stainless steel, and copper lined with plastics or glass have been produced. An interesting product of this kind is T.I. "Metica" tubing, which consists of stainless steel lined with graphite to provide a chemically inert lining. Specimen joints for "Metica" tubing were exhibited.

A typical example of the work of the company's aluminium division was exhibited in the form of a model of a heat exchanger unit embodying extruded finned aluminium tubing.

Among the interesting special-purpose fittings exhibited on the same stand were a flexible coupling made of PTFE (polytetrafluorethylene) for chemical work; and a "Chesterfield-Unisteel" coupling for joining austenitic and ferritic steel tubes, for example, between the superheater and the lower-temperature zones of boilers.

(*To be continued*)

Fretting Corrosion on a Screwed Joint Under Prolonged Fatigue Loading*

By J. E. FIELD

Numerous cases are known, both in service and in the laboratory, of fatigue cracks which have commenced at an area of fretting corrosion, such as often occurs when two parts in contact are subjected to a small relative oscillatory movement. This fretting corrosion can considerably reduce the inherent fatigue resistance of a part subjected to fluctuating stresses. Here tests of fretting corrosion on a screwed connection are described. The conclusion is drawn that the fatigue strength of a bolt is not adversely affected.

WHEN a screwed connection, such as a bolt and nut, is under load, contact under pressure occurs along one side of each of the mating thread helices. Under a cyclic load, fretting occurs along the band of contact, due to the small relative oscillatory movement between the mating threads. This fretting increases with the number of load cycles, and is usually quite severe after several million cycles, at least for bolt loads in the region of the limiting fatigue load. The fretting is usually confined to a band near the middle of the thread flanks, since these are rendered slightly convex by bending of the threads under load, and hence only make contact over a restricted area. (Bolts are usually subjected to a unidirectional tensile load). The maximum stress in the threads, which is largely due to bending, occurs, however, along a helix line near the transition from straight flank to radiused root. This has been demonstrated experimentally by photoelastic methods. Although thread errors can shift the band of contact between mating threads to different parts of the flank, it is unusual for this band of contact to overlap the localised region of maximum stress near the thread root. This probably explains why fatigue failures in bolt threads practically always begin from this region of maximum stress and not from the area of fretting corrosion on the thread flank.

It was thought possible, however, that after a considerable number of load cycles, the fretting might be severe enough to give rise to a fatigue failure initiating at the fretted area. Accordingly, a number of ¾–10.UNC bolt and nut combinations were subjected to pulsating tension fatigue tests, including one which was run at a load just below the fatigue limit, for 200 million cycles. The bolt material (EN16T) was of about 60 tons per square inch tensile strength, and the nut material (3S1 (N), similar to EN7) of about 36 tons per square inch tensile strength. The bolt threads were accurately ground and the nut threads accurately tapped. The threads were coated with a light grease before assembly. A pulsating tensile load was applied to the bolt through the nut, as in normal service. Four similar combinations were tested in all, the stress on successive bolts being reduced in small steps until one was obtained which withstood 10,000,000 cycles without fracture. The test on this fourth combination was continued until over 200 million cycles had been completed, without fracture. The stress was then increased to a value a little above the fatigue limit, and the test further continued until fatigue frac-

* Communication from the Mechanical Engineering Research Laboratory, East Kilbride. This article is published by permission of the Director of Mechanical Engineering Research, D.S.I.R.

ture of the bolt occurred. The results of the tests are given in the table.

Photographs of the threads of bolt No. 4, after fracture, are shown in Figs. 1 to 5. The left-hand specimen in Figs. 1 to 3 is a similar bolt which was broken under similar conditions after an endurance of 16,000,000 cycles. This is shown to indicate the amount of fretting obtained in a fatigue test of the maximum usual duration, in preference to one of the bolts 1 to 3 of the present series, which all broke at under 2,000,000 cycles and showed very little fretting.

The fracture of bolt No. 4 was of normal type and the fatigue crack had begun in the usual place, near the transition from thread flank to root. Heavy fretting had occurred on the thread flanks, and, at the point where the fracture had initiated, the fretting damage covered the whole width of flank right up to the edge of the fracture. It was, however, heaviest near the centre of the flank, and on a microscopic examination, no cracks were detected within the fretted area.

It will be seen from the table that the endurance of bolt No. 4, in the final test at the higher stress, was greater than that of bolt No. 1, which was tested at the same stress without previous running and without previous appreciable fretting. The heavy fretting on bolt No. 4 had thus had no adverse effect on the fatigue resistance of the bolt. The higher final endurance as compared with bolt No. 1 may be due to an understressing effect, but it is not considered that such an effect would be very great, as the understressing was only at a single level.

Results of Fatigue Tests on Bolt and Nut Combinations

Identification number of combination	Pulsating tensile stress*, tons per square inch	Endurance, millions of cycles	Stud broken (B), or unbroken (U)
1	10,000–39,000	1·08	B
4 (2)	10,000–39,000	5·07	B
2	10,000–37,000	0·45	B
3	10,000–36,000	1·84	B
4 (1)	10,000–35,000	203·13	U

* Based on area at root of bolt thread.
(1), (2): First, second test on same combination.

Conclusion

The fatigue strength of a bolt is not adversely affected by the fretting which occurs on the thread flanks under fluctuating load, due to oscillating contact with the nut threads. A crack, formed on stressing above the fatigue limit, does not start in the fretted area, which does not include the point of maximum stress at which the crack initiates. It appears that even severe fretting does not in this case give rise to a local stress as high as that obtaining near the transition from thread flank to root.

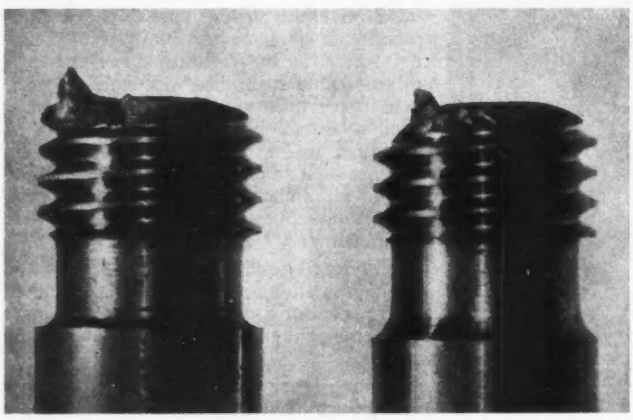


Fig. 1—Side views of broken bolts. Bolt No. 4 run to over 200 million cycles is on the right. In each case the irregular area of final fracture is to the left, and the presumed point of initiation of the fatigue fracture to the right. Both fractures are seen to have begun at the same point on the thread profile, i.e. near the junction of the flank and root radius

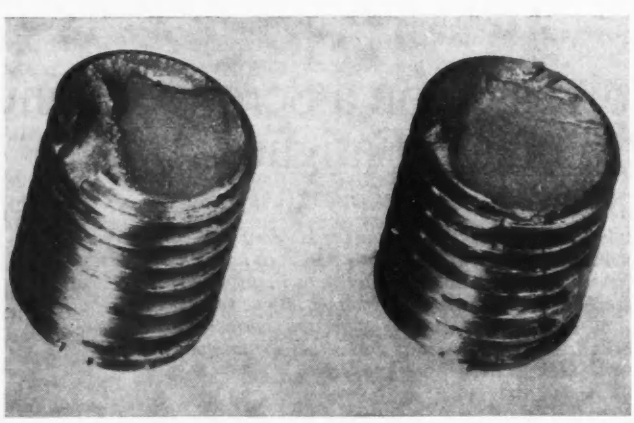


Fig. 2—Ends of bolts broken in fatigue, after removal of nuts, showing fretting on thread flanks. The stud on the left had withstood over 16,000,000 cycles; that on the right—bolt No. 4—over 200 million cycles

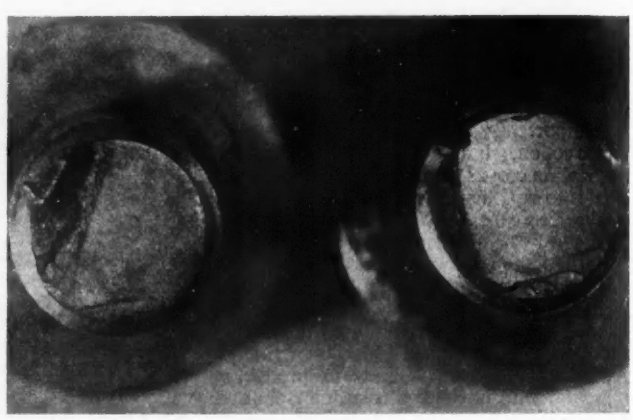


Fig. 3—Faces of fracture on longer parts of broken bolts shown in Fig. 2. The bolt on the right—No. 4—is the one run to over 200 million cycles. The small dark areas represent the final fractures. The loaded flanks of the threads are on the reverse side and practically no fretting is visible on these unloaded flanks

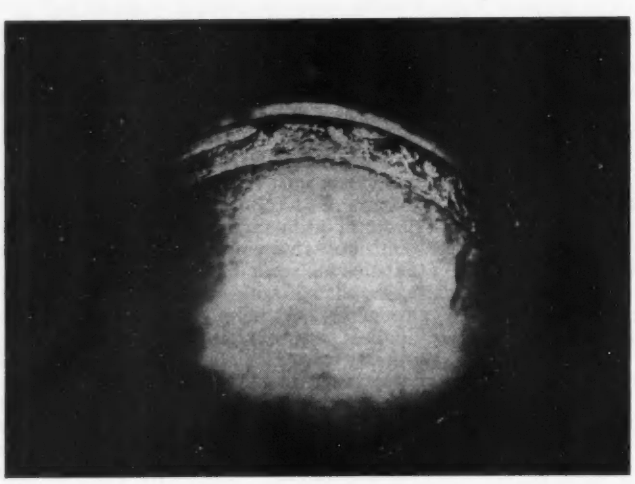


Fig. 4—Bolt No. 4. Fretted area on flank of thread, in region of initiation of fatigue fracture. The face of the fracture is at an angle to the thread flank and hence largely out of focus

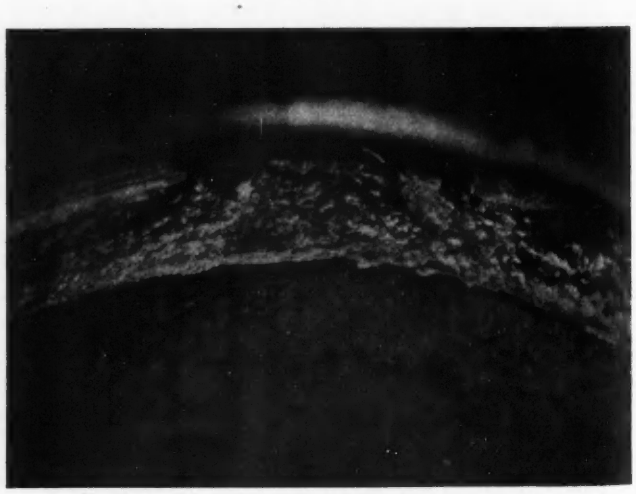


Fig. 5—Enlarged view of part of thread flank shown in Fig. 4

Lightweight Air Pressure Braking System

In reducing the weight of a power braking system, the use of higher pressures throughout the system is the most direct course. In the air pressure systems used on heavy vehicles the actuators, which are of normally unsprung weight, are very bulky, and their supply losses are also large. Great improvements, not only in weight but in speed of response, can be made by the use of hydraulic motors on the brakes. Once hydraulic actuation is accepted, servo assistance can be obtained in three principal ways, reduced air pressure or "vacuum," increased air pressure, or hydraulic pressure. The vacuum system is attractive for petrol-engined vehicles, but on a diesel it calls for an exhauster, so that on the oil-engined vehicle there is a clarion invitation to circumvent the limit of pressure differential set by the barometer and use high-pressure air.

The air-hydraulic system designed by the Bendix Westinghouse Company has been used in many countries abroad and also on vehicles acquired by the Ministry of Supply, and is now manufactured under licence by Clayton Dewandre Company, Ltd., Titanic Works, Lincoln. In this system normal hydraulic brakes are fitted on the vehicle axles, and the master cylinders are driven by pneumatic actuators; if it is desired to safeguard the vehicle against the consequences of a liquid leak more than one master cylinder can be used. The operating pressures are the normal 85–105 lb per square inch of Westinghouse systems, and standardised reservoir, governor, pressure indicators and fittings are used. The new components for the system are a reciprocating compressor, a brake control valve, and an air-hydraulic actuator.

The compressor is only 8½in high, may run up to 3000 r.p.m., and gives 4 cubic feet per minute displacement at 1250 r.p.m. It may be either lubricated from the engine oil system or self-contained. The engine lubricated model illustrated weighs 12 lb and the alternative pattern 14 lb. The crankcase is aluminium, but crankshaft, block and cylinder head are cast iron. As can be seen, the journal load of the drive belt is taken by a ball bearing and the remainder of the bearings are plain. In the self-lubricated model an eccentric between the crank throws actuates an oil pump plunger supplying oil to the drilled crankshaft. The design incorporates flat disc-like automatic inlet valves, and to unload the pump both valves are lifted off their seats by plungers actuated by air from the reservoir; the governor admits air to the unloader cavity when the reservoir reaches 100 lb to 105 lb per square inch and releases it again at 80 lb to 85 lb per square inch.

The new brake valve is of the treadle type and relates brake pressure directly to pedal movement. The central hollow piston which communicates with the atmosphere is moved down by a spring until it seats on the rubber-faced disc valve and lifts it; air will pass from under the valve until the pressure under the piston and in the actuating system rises sufficiently to compress the spring far enough to allow the disc valve to seat. Thus the braking effort depends upon the spring deflection and therefore the pedal movement. Any withdrawal of the pedal allows the air in the actuator to exhaust through the bore of the piston to atmosphere. The output pressure rises from 5 lb per square inch with 3 deg. treadle movement to 75 lb per square inch at 20 deg. travel. The valve body is an aluminium die casting.

A new line of air-hydraulic actuators offers a selection of sizes and mountings to suit various hydraulic cylinders. The actuator consists of a diaphragm clamped between domed metal plates and balanced between the air supply and a spring-loaded piston which is connected by a pushrod to the master cylinder piston. The actuator is very simple in construction and does not require any lubrication. Little maintenance is needed.

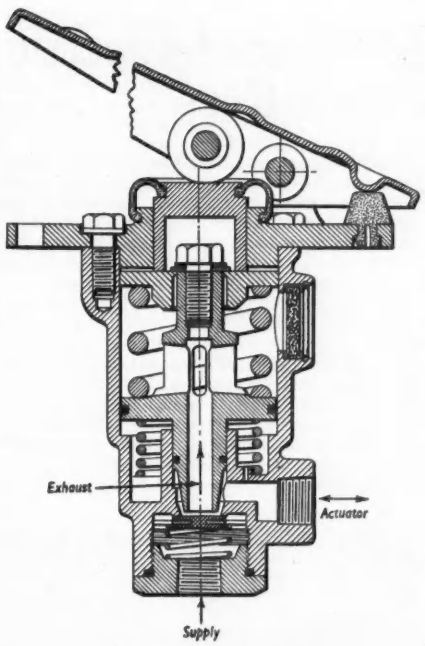


Fig. 2—The brake control valve

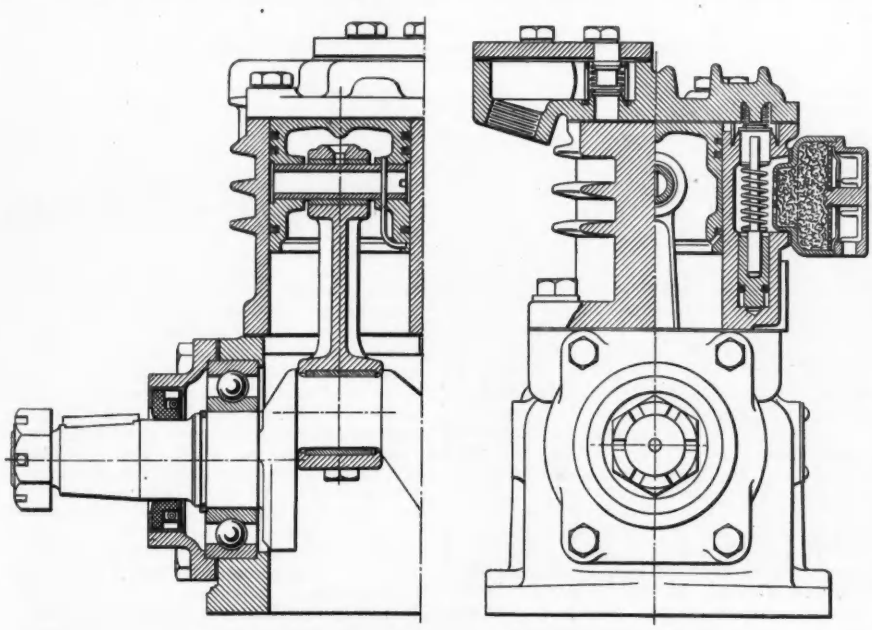


Fig. 1—Sections of engine lubricated air compressor

Since the adoption of hydraulics reduces the internal volume of the system considerably, no quick-release air dump valves are needed. The stop light switch is, however, on the air system, reducing to a minimum the number of joints in the high-pressure piping.

Sintered Borides Resistant to Molten Zinc

Molten zinc rapidly attacks the common metals of construction. The rate of attack is greatly increased at temperatures over 500 deg. Cent. There are, however, many applications where it is necessary or at least desirable, to use metal construction, such as for galvanising pots and certain parts of zinc smelter equipment. Pumps, tubing, and other components to facilitate transfer of molten zinc would be advantageous in many zinc handling operations. Parts of die casting machines are in contact with molten 96 : 4 zinc-aluminium alloys. These alloys at 400 deg. Cent. are much less corrosive to iron than is zinc. Nevertheless, under these conditions, difficulty is reported with corrosion of pistons and of the rings through which they operate. No common metal or alloy will resist both corrosion by zinc or zinc vapour and oxidation at 600 deg. Cent. Tungsten, niobium, tantalum, titanium and molybdenum-iron alloys with over 80 per cent of molybdenum are said to be resistant to molten zinc. Chromium plating has been held to improve galvanising pot life. Nitrided cast iron has been used in die casting machines in which the molten alloy is 96 : 4 zinc-aluminium.

W. Hodge, R. M. Evans and A. F. Haskins,* who have investigated the question, have not found any purely metallic material that is unattacked, but have shown that certain refractory metallic borides are resistant to corrosion by molten zinc at 600 deg. Cent. and to oxidation at higher temperatures. Coatings were made from ferroboron and from manganese-boron on a mild steel basis metal by welding, and by pack diffusion. Diffusion coatings on steel showed a tendency to crack since the coefficient of expansion of the coating was $13{\cdot}6\times10^{-6}$in per deg. Cent., whilst that of the underlying steel was $16{\cdot}5\times10^{-6}$in per deg. Cent. To overcome this difficulty, steel with 12 to 14 per cent of chromium was used, as its coefficient of expansion was nearer to that of the coating. Radial cracks were eliminated but peripheral cracks remained. Thus, mechanical failure of the diffusion coatings was only partially eliminated by the use of an expensive chromium steel. Welded coatings suffered from the same defect. Welded coatings made with a tungsten arc were better than those made by other welding methods. Sintered boride compacts were preferred. The least expensive of the resistant compacts was made from about 68 per cent of ferroboron and 32 per cent of iron. It was, however, very weak, having a tensile strength (calculated from modulus of rupture in transverse loading) of only 4·5 tons per square inch. Compacts giving about 13 tons per square inch were obtained by sintering a mixture of chromium diboride, CrB_2, and iron. These also were the most resistant to molten zinc and to oxidation. The strongest compacts (19·5 tons per square inch) were made from chromium diboride 85 parts and nickel 15 parts, but nickel boride is not resistant and the presence of 15 per cent of nickel destroyed the corrosion resistance of the mixture. Manganese boride though itself completely resistant, could not be satisfactorily sintered. Some small parts of irregular shape (impellers, &c.) were made in 85 chromium diboride 15 iron, and also in 85 ferroboron 15 iron, but were not submitted to any endurance trials. The authors, however, believe that sintered boride rings and pistons, operating in 96 : 4 zinc-aluminium alloy at 400 deg. Cent. in die casting machines would resist corrosion indefinitely and that many other useful products designed to withstand the action of molten zinc may also be made from sintered powdered borides.

* *Journal of Metals*, July, 1955, page 824.

Power Equipment for Diesel-Electric Shunting Locomotives

TEN standard 0-6-0, 350 h.p., diesel-electric shunting locomotives for British Railways have been equipped with oil engines supplied by Crossley Brothers, Ltd., driving electric traction equipment supplied by Crompton Parkinson, Ltd. The power unit comprises a two-cycle, scavenge-pump diesel engine coupled to a single bearing, self-ventilated generator supplying current for two axle-hung, nose-suspended traction motors. An auxiliary generator is mounted on the main generator from which it is belt driven. This equipment provides the required maximum tractive effort of 35,000 lb and a continuous tractive effort of 15,400 lb at about 5½ m.p.h.

One of the engines undergoing its tests at the makers' works can be seen in the illustration on this page. It is a Crossley "EST" six-cylinder engine with a bore of 7in and a stroke of 9in, arranged for port-controlled loop scavenging. It has a continuous rating of 350 b.h.p. at 825 r.p.m. and its service idling speed is 350 r.p.m. This engine, the first of its size supplied by the makers for use in diesel-electric locomotives, is particularly designed for long running periods between overhauls and ease of maintenance. The makers state that the exhaust ports will operate without need for cleaning over long periods and can be cleaned in a few minutes without having to remove the cylinder head or exhaust manifold. Quickly removable inspection doors give easy access to both the working parts of the engine and the water jacket of the cylinder heads. The connecting-rods and bearings, the governor and the scavenge pump operating gear are also readily accessible through the crankcase doors, whilst all the bearings can be removed without disturbing the crankshaft. The engine employs the exhaust pulse pressure charging system whereby pressure pulses in the exhaust system are used to top-up the air charge in the engine cylinders.

The engine and generator are mounted on a substantial steel frame, forming a complete unit which is supported on three-point suspension, comprising a pin mounting under the free end of the engine and trunnion mountings on each side of the generator. The engine or generator can be removed independently for servicing.

The cast iron base plate of the engine, which carries the crankshaft, is of rigid girder design. The cylinder block and crankcase form a single deep monobloc casting with through bolts up to the cylinder block level. All cylinder blocks are fitted with detachable liners, the design being such as to avoid the use of a massive flange at the upper end of the liner, and incorporating uncooled port bars for the air and exhaust ports.

Ample water passages are provided in the cylinder heads to minimise heat and other stresses. As the cylinder heads are free from poppet valves with their associated ports, a relatively large number of equally spaced holding-down studs are fitted and this reduces bending stresses due to radial expansion and eliminates any tendency to stud failure.

The crankshaft, machined from a 50-ton carbon steel forging, is provided at both ends with an integral coupling flange and is fitted with a torsional vibration damper. Crankshaft bearings of steel are lined with strongly bonded whitemetal and the bearing caps are securely spigoted to the base plate. The connecting-rod large end bearings consist of steel housings lined with heavy-duty whitemetal, and the piston pin bearings are of hard phosphor bronze. The oil-cooled pistons, of trunk design, are ground and tin coated, and each is fitted with gas pressure and oil scraper rings.

The double-acting tandem scavenge pump, located at the forward end of the engine, is driven by a separate crankshaft bolted through a flanged coupling to the main cranskhaft at the opposite end to the flywheel. Its crosshead and lower piston are cast in aluminium alloy and a hollow high-tensile steel piston-rod carries the upper piston. Automatic ring-valves provided in the pump can be lifted straight out of the cylinder, after the top cover has been removed. The operating lever of a centrifugal governor is coupled to the fuel pumps and varies the point of cut-off of the fuel injection. Thus, the injection timing remains constant, whilst the duration of injection varies according to the load. This governor has complete control throughout a range of engine speeds.

The fuel pumps are assembled in a unit at the control end of the engine and are driven through spiral gearing. Each pump operates entirely upon the port control principle, and can be accurately balanced by a simple adjustment to deliver its correct quantity of fuel. The fuel sprayers fitted are of the Crossley precision design and all their parts can easily be taken apart for inspection.

Cooling water is circulated by a centrifugal pump mounted on the free end of the engine and thermostatic controls are incorporated to maintain the water at operating temperature under all conditions. The lubricating oil system is fitted with "full flow" and "by-pass" filters, and protection against low oil pressures is provided by a pressure switch coupled with the engine valve which controls the fuel supply to the fuel pump.

The main generator has a one-hour rating of 220kW, 570A, 385V, 825 r.p.m., and a continuous rating of 214kW, 492A, 435V, 825 r.p.m.

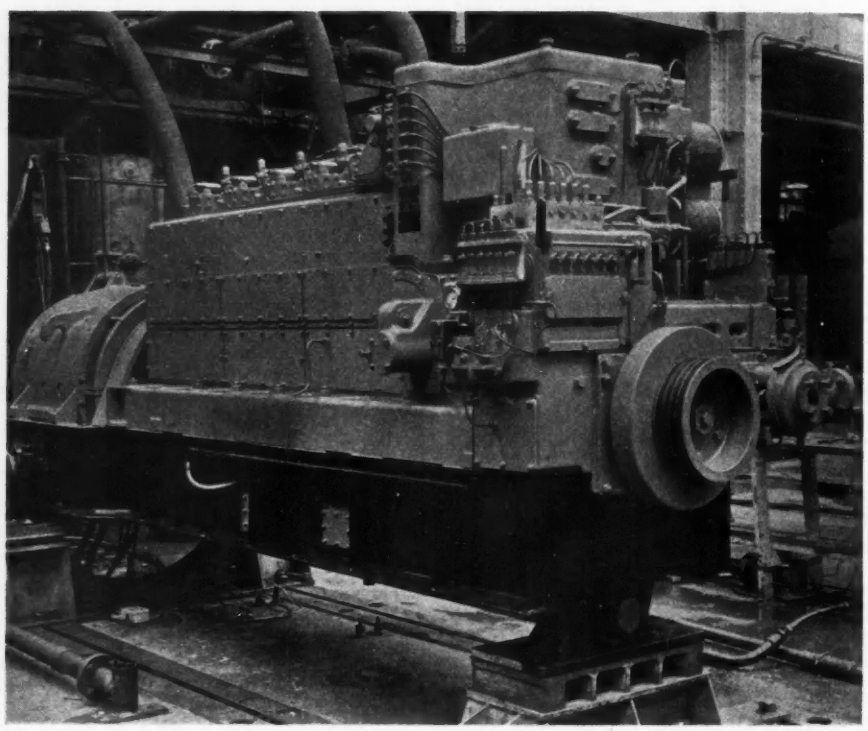
It is a single-bearing, self-ventilated machine, rigidly coupled to the engine. A special hand barring gear embodied in the coupling end of the rotor consists of a rotor-mounted, notched ring actuated by a detachable hand lever, and it provides a simple means of turning over the whole engine generator shaft assembly.

The magnet frame is of cast steel. Its mountings include vertical and horizontal bases whereby the main generator frame is attached to the fabricated engine under-bed, and this, in turn, is bolted to the engine crankcase.

The generator has three field windings, i.e. self and separately excited shunt windings, and a series winding which is used only for starting purposes. Its characteristics have been so designed that no complications such as separate exciters or regulating devices are necessary and, at the same time, risks of overloading the engine beyond predetermined limits are avoided. Both the field and the armature coils have been fully pressed and impregnated to eliminate shrinkage during service and ensure rigidity, freedom from breakdown and close dimensional tolerances. All the field coils are arranged in separate sections and each section embodies substantial terminals to receive the external connections. The main insulation is carried throughout the complete length of the armature coils.

The auxiliary generator, situated on the main generator, has a centrifugal blower mounted on it for the forced ventilation of the traction motors—an arrangement designed to obviate the need for more than one belt drive from the main generator. The one-hour rating of the auxiliary generator is 90V, 13·5kW, at 1165/2750 r.p.m., and the continuous rating is 90V, 12kW, at 1165/2750 r.p.m., the corresponding engine speeds being 350/825 r.p.m. The auxiliary generator voltage is maintained at 90V by means of a carbon-pile automatic voltage regulator installed in the driver's cab.

The two axle-hung, nose-suspended traction motors have double reduction gearing, one gear wheel and pinion being accommodated at each side of each motor. The layshaft joining the first and second gear trains is carried on roller bearings, and is mounted in an eccentric shaft. Through this eccentric shaft the drive can be easily demeshed if the locomotive has to be moved at speeds in excess of 20 m.p.h. In the drive the layshaft, the armature shaft and the axle are all lined up in the same plane. This has resulted in the use of a motor of relatively small overall dimensions, ample clearance being provided between the motor frame and the locomotive footplate to simplify erection and servicing. The armature pinion, as well as the pinion and gear wheel on the layshaft, is arranged for removal when necessary by high-pressure oil injection. The necessary resilience of the nose-suspended motors is given by rubber springs located between the nose supports and the fixing on the locomotive frame. Conventional suspen-



350 h.p. diesel-engine-driven generator set for shunting locomotive

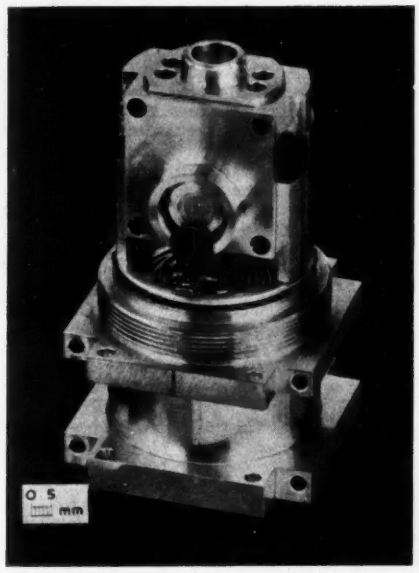
sion bearings are used, but to simplify maintenance Armstrong lubricators are fitted.

The control gear, designed and made by Allen West and Co., Ltd., to Crompton Parkinson requirements, is contained in a single desk cubicle located in the driver's cab and has controls which are to the standard B.R. pattern. The power circuits are also of British Railways standard in that the two traction motors are connected in parallel across the main generator. No series-paralleling arrangements are provided, however, since it was considered that the capacities of the generator and the motors would be ample for all varying duties that the locomotives would be called upon to perform, including hump shunting, without resorting to this expediency. However, a switch has been included which weakens the field of the main generator, thereby enabling the speed of the diesel engine to be raised and so increasing the quantity of air supplied to the traction motors. This switch can be used when particularly heavy loads are being hump shunted.

Each motor is controlled by its own contactor and protected by its own overload relay. The general system is earthed through an earth-fault relay, which provides protection both to the generator and the motors. Each motor can be isolated, if ever necessary, by means of the isolating links provided in the control cubicle.

Aircraft Crash Accelerometer

An instrument for recording the deceleration experienced at the moment of impact by an aircraft involved in a crash has been designed by the National Physical Laboratory for the Ministry of Supply. Known paradoxically as an accelerometer, it is intended to be fitted to an aircraft in one or more places, is inexpensive and weighs just over 1 lb. It will remain in working condition without requiring attention and is



Crash accelerometer with cap removed showing stylus and recording disc. The cylindrical base contains the spring mass and dashpot.

capable of surviving any possible crash, and the effects of fire up to a temperature of 400 deg. Cent.

Our illustration shows the accelerometer with its airtight cover removed. In the bottom cylindrical portion is situated a single mass-spring accelerometer with air dashpot damping, having a natural frequency of 100 c/s, and being approximately critically damped. It covers the range 0 *g* to 50 *g*, with an accuracy of ±5 per cent up to 1 *g*, and a 95 per cent response in 0·01 seconds to a quasi-square acceleration pulse.

The top portion contains the recorder, consisting of a stylus attached to the mass, which scribes a trace on a rotating gold-spluttered glass disc. The disc is rotated by an A.A. fuse clockwork at the rate of one-third revolution per second, giving a time resolution of 0·017 second. Release of the clockwork occurs, with a time lag of 0·017 second, when the retardation exceeds 5 *g*. Transit locking is provided for both accelerometer and record motor.

The instrument is statically calibrated by deadweight loading, and is then tested in an electro-mechanical pulse generator in order to find its dynamic response. Finally, the damping is adjusted so that there is no overshoot for a quasi-square pulse.

Another Nimonic Alloy

The progress of British gas turbines has been linked intimately with the Nimonic series of alloys, and a new member of the range has now been introduced by Henry Wiggin and Co., Ltd., Wiggin Street, Birmingham, 16. Nimonic 100 has very high resistance to creep and may be used at temperatures some 30 deg. Cent. higher than its predecessor, as shown by the following table.

Alloy	Temperature for fracture in 100 hours at 5 tons per square inch.
Nimonic 80A	870 deg. Cent.
Nimonic 90	900 deg. Cent.
Nimonic 95	925 deg. Cent.
Nimonic 100	950 deg. Cent.

Several gas turbine builders have already received quantities of the new alloy for development purposes and for design purposes the following table of creep properties is published.

Stress to Rupture Properties of Nimonic 100

Temperature deg. Cent.	Stress (tons per square inch) for rupture in		
	50 hours	100 hours	300 hours
870	13·5	12·0	9·5
925	8·5	7·0	5·5
940	6·7	6·0	4·5
980	4·0	3·5	3·0

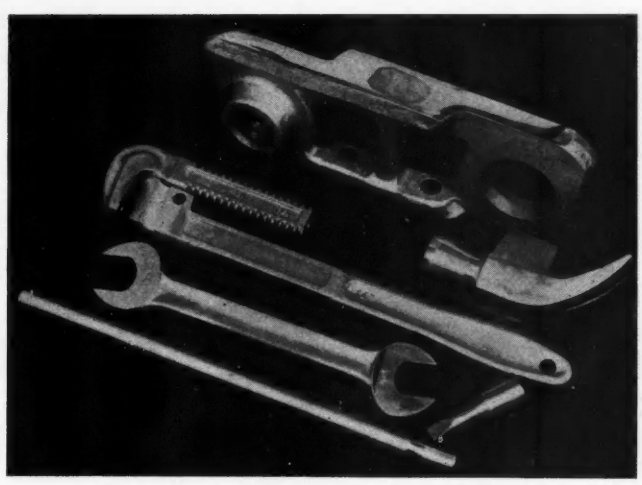
Metallographic Examination of Forgings

For the control of heat-treated forgings a microscopic examination of crystal structure is valuable, but this technique is limited if specimens must be cut out and mechanically polished. A method of chemically polishing plain carbon steel, originally invented at the Armament Research Establishment, Woolwich, has now been developed by the Guest, Keen and Nettlefold Group Research Laboratory and adopted for routine inspection by Garringtons, Ltd.

The process uses a mixture of hydrogen peroxide and oxalic acid, either the part being immersed or the solution poured inside a plasticine wall on the surface. The chemical polishing has an etching effect and renders crystal structure visible under the microscope. The finish obtained has a definite corrosion resistance and no adverse effects on fatigue properties are suspected.

Pearlite and ferrite in flame hardened jaw of wrench Magn. × 800

The illustrations show typical components inspected by this method, and the crystal structure of one of these forgings. The polishing treatment may take from five to thirty minutes.



Forgings partly polished by chemical methods for microscopic examination

Aluminium Industry's Centenary

The centenary of the founding of the aluminium industry by H. Ste. Claire Deville in 1855 has been the occasion of the publication of several monographs, including one by Dr. T. G. Pearson entitled "The Chemical Background of the Aluminium Industry."* The extraction of aluminium, from the mining of bauxite to the production of the metal in its purest form, is reviewed with special reference to underlying chemical principles. It is a remarkable fact that, in spite of the great increase in output and the accompanying development work, the essential features of the industrial process have remained unchanged for sixty years, though numerous detailed improvements have been made to increase efficiency and improve quality. In the production of pure alumina from bauxite, the process as worked to-day is essentially identical with that invented by Bayer in 1888, and as long as there is an adequate supply of good-quality bauxite with less than about 7 per cent silica it is improbable that any other process will supersede it. Similarly, no radical departure from the essential features of the Hall-Héroult process (1894) has yet been achieved on the industrial scale. Meanwhile the underlying chemistry of these processes has been the subject of extensive research in the light of which further improvements may be possible and other lines of treatment may be explored. This work is well summarised, with over 300 references to original papers, in Dr. Pearson's 100-page monograph, which should be most valuable to anyone interested in the metallurgy of aluminium.

* Royal Institute of Chemistry: Monograph No. 3, 1955.

Diesel-Electric Paddle Tugs

THE ability to develop great astern power has kept paddle propulsion alive very notably among tugs. The Royal Navy has ten paddle tugs, two of which were built in the nineteenth century, and the newest of which were constructed during the first world war. These vessels have proved to be the most suitable tugs for handling large warships in dockyard basins and through entrances. The Admiralty now has a programme for the construction of seven diesel-electric paddle tugs to replace some of the existing fleet, and the first two, to be laid down very shortly by Yarrow and Co., Ltd., Scotstoun, Glasgow, will be named " Director " and " Dexterous."

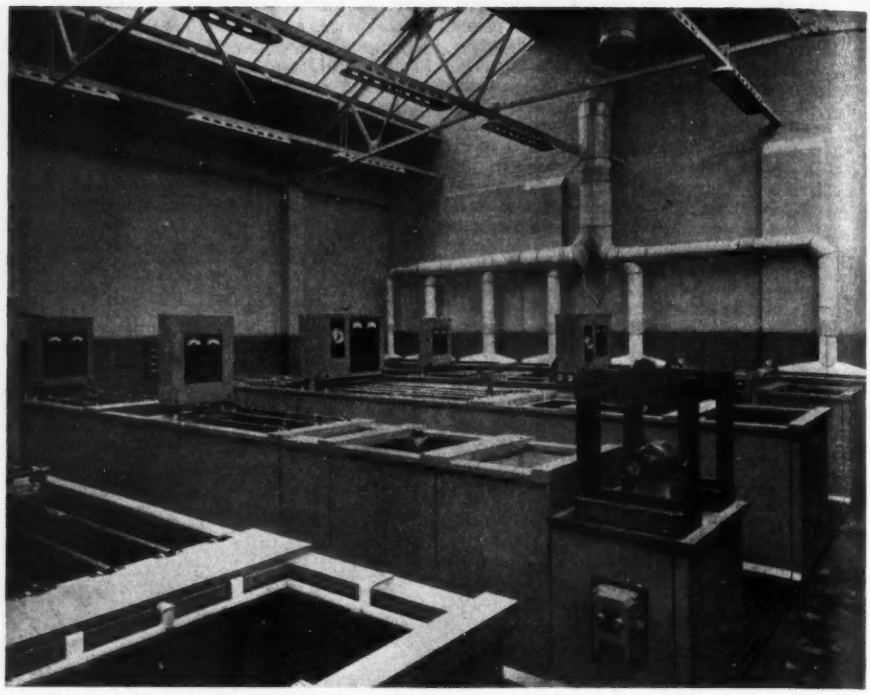
The projected tugs will be built to Lloyd's Class 100 A1 and be able to undertake towing and salvage at sea. The design is markedly influenced by the need to operate under the overhanging sides of aircraft carriers, the masts being hinged ; twin funnels are fitted, but are abbreviated.

Principal particulars of the vessels are as follows : length overall, 157ft ; breadth overall, 60ft ; draught, 10ft ; speed, running free, 13 knots ; bollard pull, estimated, 15 tons ; displacement, 710 tons.

The main engines are four Paxman 12 YMAX units, coupled to 339kW 1600 r.p.m. d.c. generators. There are two propulsion motors of 800 h.p. at 212 r.p.m. driving through chain reductions of about eight to one to the paddle shafts ; the shafts can be coupled together by a dog clutch. The motors, control gear, and generators are to be manufactured by The British Thomson Houston Co. Ltd. ; each motor can be controlled either from bridge or engine-room, and two different power characteristics are provided. Flexible couplings are incorporated between each motor and its pinion shaft, while these and the wheel shafts are supported on roller bearings.

Apart from a 16 cubic foot diesel air compressor, the principal auxiliaries are motor driven from the output of four Foden two-stroke six-cylinder diesel generators. These include a 150 tons per hour fire and salvage pump supplying two monitors and two foam distributing heads, two 30 tons per hour bilge and fire pumps, an 800 gallon per hour diesel oil transfer pump, a 16 cubic foot air compressor, and Alfa Laval diesel and lubricating oil purifiers. Each machinery item can quickly be removed for repair ashore.

The new design forms an interesting contrast to the last British diesel-electric paddler, the " Talisman," built in 1935 with four 600 r.p.m. generators supplying a 1300 h.p. motor direct coupled and running at 50 r.p.m. Her gross tonnage was 544. Post-war British paddle vessels have had mechanical transmissions ; the " Mary Queen of Scots," of 230 tons, had a 150 b.h.p. two-stroke diesel running at 625 r.p.m. geared to each paddle with a ratio of approximately 15 to 1.



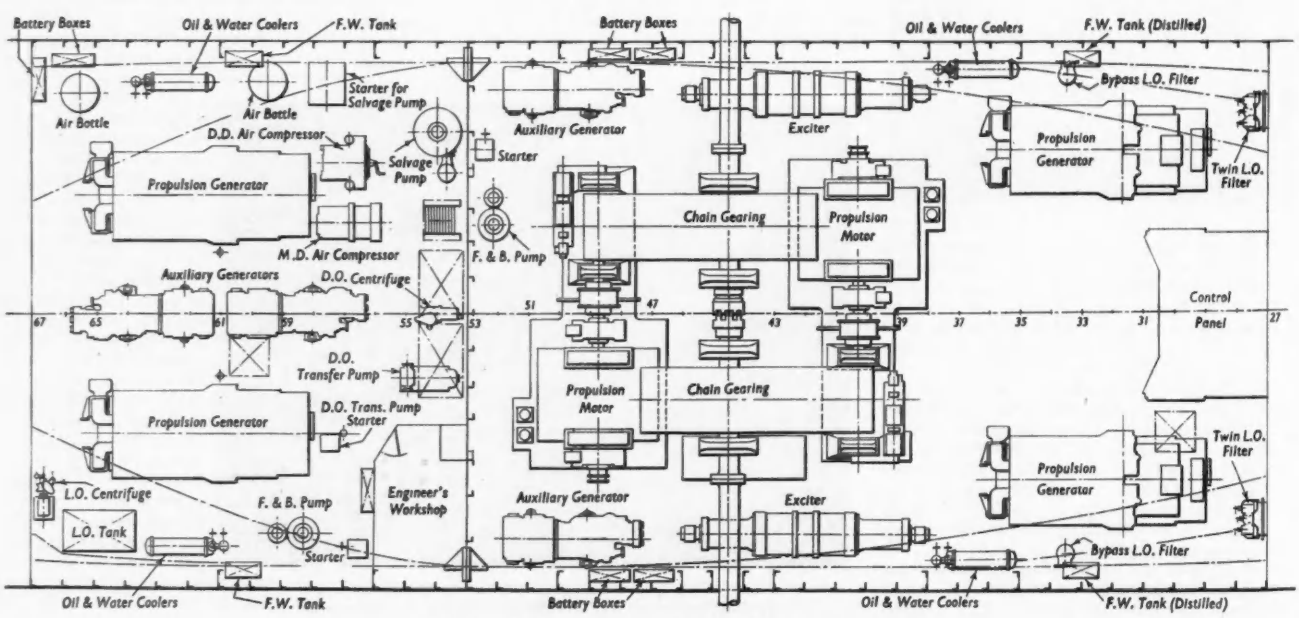
The plating shop. The ducts on the end wall abstract fumes rising from the tanks below

Construction in Vinyl Sheeting

A NEW plating shop for the English Electric Company Ltd. at Stafford has been fabricated by W. Canning and Co., Ltd., largely from " Cobex " rigid vinyl sheet, made by B.X. Plastics, Ltd., Higham Station Avenue, London, E.4. " Cobex " is said to have certain practical advantages for this application, since it is almost completely resistant to inorganic chemicals, has a pleasing surface finish which is easily cleaned, and, being thermoplastic, it is easily worked.

In the plating shop, which we illustrate, " Cobex " is used in two main forms ; the piping inside the vats consists of extrusions joined by hot torch welding, while the aprons, linings and lids of the vats, the trunking and the panel facings are made of laminated Cobex/Velbex sheet. " Velbex " is a flexible vinyl sheet, and the laminate has a higher impact strength than the rigid sheet and can be fixed to metal without adverse effects from differential expansion.

" Cobex " alone has a resistance to shock comparable with that of cellulose acetate, and is claimed to possess a high degree of dimensional stability. Threads may be cut in it with ordinary taps and dies, coarse threads being most satisfactory, and machining presents little difficulty ; for turning, a feed of 0·002in to 0·005in at 400ft to 500ft per minute is recommended. It can be cemented to a variety of organic substances with a joint efficiency of about 30 per cent, and can be joined by fusing in a filler rod with a stream of air at 300 deg. Cent. The sheet can most readily be moulded at 100–120 deg. Cent. and if reheated will revert to a flat sheet. The material is suitable for application where its temperature will not exceed 60 deg. Cent. Acute embrittlement is not experienced above −40 deg.



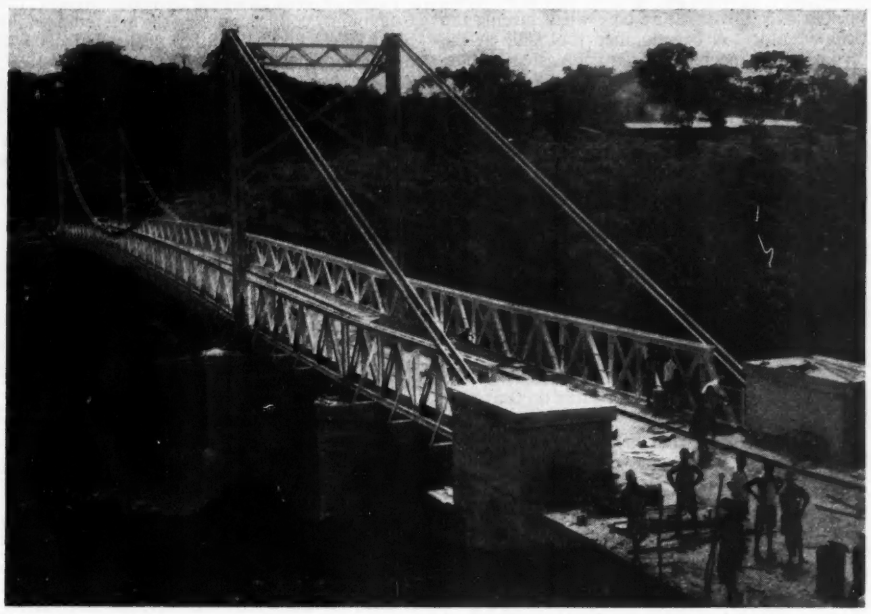
Machinery arrangement in the new Admiralty paddle tugs

Cross River Bridge, Nigeria

We illustrate herewith the newly-completed suspension bridge spanning the Cross River in Nigeria, which, the contractor informs us, has been completed six months ahead of the scheduled time. The bridge is situated in a particularly inaccessible spot, and difficulties in organising the constructional work and obtaining supplies of materials had to be overcome.

The bridge has a central span of 350ft, which is suspended, with straight back stays, and three short independent approach spans, two of them on the left bank, from 45ft to 50ft in length. This layout is clearly shown in the illustration, and was advantageous for the conditions of this particular site. The total length of the bridge is 590ft and the principal piece of plant used to erect it was a 6-ton Blondin cableway.

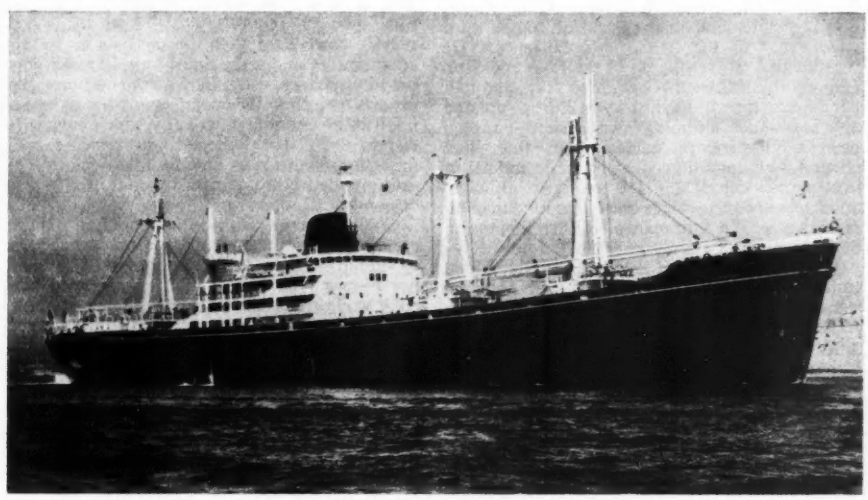
The bridge carries the principal highway connecting Nigeria with Central Africa, and was built for the Crown Agents for Overseas Governments on behalf of the Nigerian Government. The consulting engineers for the bridge were Messrs. Coode and Partners, and the main contractor was Dorman, Long and Co., Ltd. The bridge was described in a paper by Mr. K. E. Hyatt, presented to the Institution of Civil Engineers' colonial conference of 1954, substantial abstracts from which were published in The Engineer of June 18th of that year.



Suspension bridge of 350ft main span over the Cross River, Nigeria. The bridge replaces a ferry, and is an important improvement in Nigerian road communications

Cargo Liner "Godavery"

We illustrate here the single-screw motor cargo liner "Godavery," which is the first of a class of ten such ships, ordered by the Messageries Maritimes for the Far Eastern service of the company and which has completed trials and has been handed over by her builders, the Chantiers de Provence et Port-de-Bouc. The ship has a length overall of 488ft 4½in, a length between perpendiculars of 467ft 8in, a breadth moulded of 61ft 8in and a depth to the shelter deck of 38ft 11in. A deadweight of 8300 tons is carried on a loaded draught of 25ft 7in and the full load displacement is 14,079 tons. Comfortable accommodation is provided for six passengers in two-berth and single-berth cabins. Welding has been largely used in the construction of the ship, which has three complete steel decks, seven water-tight bulkheads and five cargo holds, and these, together with their 'tween decks, have a bale capacity of 530,000 cubic feet. Macgregor steel hatch covers are fitted and the hatchways are served by one 60-ton, one 30-ton, four 10-ton and ten 5-ton derricks operated by fourteen 5-ton electrically-powered geared winches. Three diesel-driven generators provide the necessary electrical power and there is a 30kW emergency generator. A special compartment is provided for the carriage of explosives. The ship, which has a speed of 16 knots and radius of action of 12,000 miles, is driven by a single-acting, two-stroke Burmeister and Wain diesel engine, built by the Forges et Acieries du Creusot (Schneider), which develops 8300 b.h.p. at 115 r.p.m., and 9130 b.h.p. at 119 r.p.m. for twelve hours. One forced circulation exhaust gas boiler is fitted and also an auxiliary oil-fired boiler for port use. The engine-room auxiliaries include two 50 tons per hour bilge pumps, two 75 tons per hour general service and fire pumps, a ballast pump rated at 100 tons per hour and 5 tons per hour pumps for the fresh-water and sea-water services. There is also a pump with a capacity of 100 tons per hour for handling the vegetable oil carried in two removable tanks, each of which has a capacity of 20,400 cubic feet.



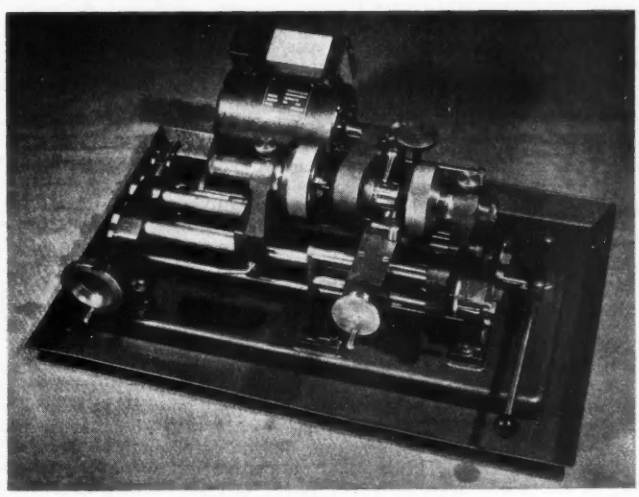
Cargo and passenger liner "Godavery"

Lathe for Commutator Turning and Undercutting

As a result of long experience in the manufacture of armatures in the shops of Browning's Electric Company, Ltd., Boleyn Castle, Green Street, London, E.13, the firm has now developed a small turning and undercutting lathe suitable for use on long-run production or in general repair shops. The machine illustrated here is designed for armatures up to 6in diameter and commutators up to 4in diameter, with bearing journals up to 1in diameter and 9in between journals. Any length of shaft extension can be accommodated provided its diameter is under 1in.

As can be seen, the machine is built up on a substantial swarf tray, with rigid brackets supporting bar form slideways carrying the main assemblies. In it the armature is held by means of its bearing journals between two self-centring, three-jaw steadies. One steady is carried by a fixed bracket and the other on an adjustable bracket, which can be positioned and locked on the bar slides in accordance with the length of the armature being machined. This method of holding the work ensures that a commutator is turned true with its bearings.

A ½h.p. motor at the rear of the machine drives



Commutator turning and undercutting lathe

the work through an endless flat belt which passes over the armature core when turning the commutator. A bar-mounted tool slide at the front of the machine carries a tungsten carbide turning tool, the setting of which is effected through a handwheel graduated in 0·001in increments. The tool slide is traversed along the work by a fine-pitch leadscrew operated by a small handwheel.

To undercut a commutator after turning, the flat belt drive is transferred from the armature to an intermediate pulley assembly below, whence, through a crossed round belt, drive is transmitted to the rear end of an undercutting saw spindle. This spindle is mounted on a bracket, through which the height of the saw is adjustable in accordance with the size of the commutator and required depth of undercut. To traverse the saw along the commutator the bracket is moved along on its slide bars by the lever to be seen projecting forwards on the right-hand side of the machine. An adjustable stop is fitted to control the length of undercutting saw traverse.

The motor is mounted on a carriage which can be moved through a handwheel at the left-hand end of the machine, to adjust belt tension and facilitate belt changing between the turning and undercutting operations.

Continental Engineering News

European Coal and Steel Community

On August 10th, the president of the High Authority of the European Community for Coal and Steel, Monsieur René Mayer, issued a statement on the occasion of the third anniversary of the Authority's existence. He recalled that the setting up of the Coal and Steel Community in Luxembourg three years ago had for the first time in the history of Europe created an economic authority with supra-national powers. Experience gained since then had created new conditions for the basic industries in a market comprising 160 million consumers, and had helped to achieve one of the fundamental objectives of the Schuman plan, the elimination of national antagonisms.

The report of June, 1955, of the Economic Commission for Europe (E.C.E.) in Geneva, sums up the position by saying that " the High Authority had achieved its initial objective of setting up a common market, and was now tackling such problems as the simplification of administrative regulations, the abolition of formalities affecting trade between member countries, the complete removal of discrimination in transport rates, the full application of the Treaty provisions concerning agreements and arrangements affecting prices, and the harmonising of internal taxes and the impact of social charges."

Against the background of the general economic expansion of the western world, the Community occupies an exceptionally favourable position. The industrial index of production in the Community countries for the first six months of 1955 rose by 12 per cent as compared with the same period the year before. This compares with 7 per cent in Great Britain and 9 per cent in the United States. Throughout the member states the rise in activity is particularly brisk in the industries producing capital goods and durable consumer goods, as, for instance, the iron and steel industry, the electrical and engineering industries, and the building trade.

In the iron and steel industry the overall volume of orders continues to increase. During the first six months of this year it rose from 11·7 to 13 million metric tons, in spite of there occurring a slight fall in the monthly orders for rolled products (3·5 to 3·3 million tons). The drop mentioned was mostly in respect of orders by third countries, and is said to be due mainly to the works trying to adjust the acceptance of new orders to their actual production. For the period January-June, crude steel production reached a monthly average of 4·3 million metric tons, an increase of 25 per cent over the comparison period 1953. This is an annual output of 51·5 million metric tons, whereas Great Britain produced 20·5 and the U.S.A. 103·8 million metric tons.

Trade in iron and steel products between the Community countries during the first four months of 1955 reached a monthly average of 470,000 metric tons, i.e. 2·7 times as much as in 1952. Almost half this figure is accounted for by German purchases from France and the Saar, Belgium, Luxembourg and the Netherlands. Conversely, deliveries from Belgium, Luxembourg and the Netherlands have also been increasing. Purchases by Italy and Belgium in the common market have almost doubled, and French purchases now stand at 50,000 metric tons a month, as compared with only 2000 metric tons monthly in 1952. This brisk exchange of trade has been encouraged by the absence of dual pricing, which is forbidden by the Community Treaty. A comparison with prices on the world market shows that the removal of internal barriers has had a stabilising effect. In spite of the fact that some price increases have taken place, basic steel prices have, on the whole, remained close to the moderate level prevailing at the time when the common market was first introduced. Both in Britain and in the U.S.A. the increases which have occurred are much more substantial.

The demand for fuels continues to expand steeply, mainly as a result of the increase in iron and steel production, but also because of the growing demand from third countries. Although it was found possible to raise hard-coal production by 3 per cent during the first half of the year, this is insufficient for the growing demand. It will be necessary to fall back on imports of American coal which, until the autumn of last year, stood around 560,000 tons a month, but have in recent months increased to over 870,000 tons.

It is considered that the coal deficit of the community can, for the time being, be made good only by such imports. The maintenance of coal exports to other European countries is looked upon as an economic necessity which cannot be disregarded. The largest coal-producing area, the Ruhr, has tried to find an intermediate solution by delivering American coal to its own customers.

Coal deliveries within the common market are being concentrated on consumers who are of vital importance to the economy, so that there has been a falling-off in the exchanges of hard coal, while coke deliveries have increased under the pressure of the demand from iron and steel plants.

During the first six months of this year, the German Federal Republic supplied some 600,000 tons of coal per month to France and Luxembourg, as against an average of 540,000 in 1954, whereas German hard coal deliveries, which in 1954 still amounted to more than 1,000,000 tons, have dropped to 800,000 tons a month.

In the long run, the problem will have to be solved by calling upon other forms of energy to fill the gap, and member governments have been giving their attention to the question of a common policy on energy without which no real progress can be made.

The direct intervention in economic affairs by the High Authority during the last three years has been guided by restraint and circumspection. In the coal section, the authorisation of prices for zone-delivered coal has been extended, and provisional arrangements have been made in respect of French subsidies before these are finally abolished. Maximum prices have been fixed for Ruhr coal which take into account the rise in costs due to wage increases. The compensation scheme for the Belgian industry has been amended, thus making it possible to concentrate financial help by the High Authority and the Belgian Government upon the marginal enterprises, and to prepare for their integration into the common market.

In the iron and steel industry, measures have been taken which will facilitate the safeguarding of scrap supplies and other essentials on a long-term basis. Out of the compensation fund for imported scrap, which has been in existence since 1953, bonuses are awarded for the increased use of pig iron whereby the industry's dependence on scrap is to be lessened.

In the transport sector, discriminatory special tariffs were abolished, and on May 1st last, a beginning was made with the general introduction of international through-rates, which, from that date, came progressively into force for coal and iron ore, and will be introduced for steel and scrap as from May 1, 1956. The High Authority has obtained the necessary directions from the Council of Ministers to enable it to negotiate with third countries concerning the application of the same rules to transit traffic.

On July 1, 1955, the rate of levy on coal and steel production was reduced from 0·9 per cent to 0·7 per cent, and will be further reduced to 0·45 per cent on January 1, 1956. It is expressly stated that this reduction will in no way affect the credit standing of the High Authority or the financial conditions necessary to the fulfilment of its several functions.

On the financial side, loans have been raised in member countries over and above the American loan, for the construction of workers' houses, of which the first have meanwhile been completed in the Ruhr coalfield and in the Nord/Pas-de-Calais basin.

With the active co-operation of the High Authority measures have been prepared by member governments to ensure freedom of movement for workers, and a point has been reached where the appropriate official regulations can be announced and a European labour card introduced in all the countries of the Community. Preliminary studies have been made on comparative real wages among coal miners and iron and steel workers.

In the immediate future, the High Authority will be concerned with measures in line with the resolutions of the Messina conference of Foreign Ministers on June 3, 1955, concerning the extension of European economic integration. Such measures will seek to bring the common market into full play and to establish it more and more firmly, and, secondly, to draw on experience and a study of existing pattern for establishing a common economic policy for Europe. To this end the Authority has participated in the discussions of experts which, following the Messina conference, were held in Brussels in July.

In order to create ultimately a general common market, there was a need, the Authority states, for doing things in stages and by transitional measures. In its experience, success would come only if all the parties concerned realised that the development was ultimately inevitable. In the case of coal and steel, this realisation had come through the fact that a treaty was in existence which laid down definite time limits for the completion of the various stages.

Thirtieth European Fair at Strasbourg

This year's Strasbourg European Trade Fair will be held from September 3rd to 18th in the park of Wacken, Strasbourg. Some 3500 exhibitors from all over the Continent will be showing their products in twenty-five exhibition halls at a show which last year attracted three-quarters of a million visitors, making it the second largest French trade fair after the Paris Fair. British engineering will be represented by manufacturers of agricultural and horticultural machinery, building and public works equipment, electrical equipment, special-purpose machinery, engineering accessories, and office and printing machines. Inquiries should be addressed to R. C. Liebman, 178, Fleet Street, London, E.C.4.

International Institute of Welding

The 1955 congress of the International Institute of Welding will take place in Zurich from September 12th to 23rd. It will be devoted to the discussion of problems from the following fields : hydro-electric power stations, water and steam turbines, and electric equipment for power stations. Following the discussion meetings, there will be meetings of fifteen sectional committees which will be concerned in a general manner with the many problems arising in modern welding technology. From September 19th to 23rd visits will be undertaken to electric power stations and several factories in order to study practical welding applications. Information about the congress, which will be held under the presidency of Professor E. Amschutz, director of E.M.P.A., can be obtained from the Secretariat of the Swiss Acetylene Association, Basel 6, St. Albanvorstadt 95.

Industrial and Labour Notes

T.U.C.'s Annual Report

The Trades Union Congress has published the annual report of its general council. This document, which will be presented at this year's Congress to be held at Southport, is a record of the general council's activities over the past twelve months. It contains, for example, an account of the part played by the general council in recent industrial disputes. About this particular aspect of its work, the general council comments that, in the light of recent experience, it proposes that, according to the circumstances, it "should be able to assist in disputes before negotiations have broken down and the point of deadlock has been reached."

On economic affairs, the report expresses the general council's "grave disquiet about the effects of Government policy." It says that "despite repeated trade union warnings, the Government has revealed no positive plan to increase industrial investment, to keep down costs and prices and to stimulate production." Instead, the report claims, the Government has allowed increases in profits and in dividends, often accompanied by the issue of bonus shares, to outstrip increases in wages. The general council, the report adds, is concerned that the Government is not doing all that it can to enable British industry to meet on the best possible terms the increasingly fierce competition in the export markets.

Another matter to which reference is made in the report concerns trade union finances. On this it is stated that, early this year, the general council decided to review the situation and carried out a preliminary survey of the experiences of a representative number of affiliated unions. The report says that the results for the different unions varied, but "the survey disclosed a situation which was anything but satisfactory."

Overseas Trade

The final figures for the United Kingdom's overseas trade in July give the value of exports as £223,000,000. The Board of Trade says that this was 42 per cent above the exceptionally low total recorded for June, but was 4 per cent below the average monthly rate in the first half of this year. The recorded value of imports in July was £338,800,000, which was 7 per cent above the average monthly rate in the first six months of the year.

Commenting on the July figures, the Board of Trade says that most classes of United Kingdom exports which suffered most severely in June on account of the railway and dock strikes showed the biggest improvement in the July figures. But exports of engineering products, which declined in June in the same proportion as all United Kingdom exports, recovered in July to a somewhat less extent than exports as a whole. On the other hand, the July figure for exports of metals increased to nearly £29,000,000 and was thus about 56 per cent in advance of the June value.

Labour Costs

In our last issue, brief reference was made to the survey of labour costs, which has been made by the Treasury, and some observations on which are published in the current number of *Bulletin for Industry*. In these observations it is emphasised that the two main threats to British competitive power in world markets are excessive home demand, absorbing goods that should be exported, and money incomes growing faster than output, causing costs, and therefore prices, to rise.

The Treasury's examination has shown that between 1948 and 1954 labour costs per unit of output as a whole appear to have risen by about 27 per cent. In the industries which are included in the Index of Industrial Production (mining and quarrying, manufacturing, building and contracting, and gas, electricity and water supply), labour costs rose by 21 per cent. The rise in mining and quarrying—predominantly coal mining—was around 30 per cent; in manufacturing industry it was 20 per cent; in building and contracting, 32 per cent, and in electricity, gas and water, 15 per cent. In what the Treasury describes as the "service" industries, labour costs in the transport and communications group covering both the railways and roads, showed an increase of about 12 per cent, and in the "distribution" group the increase was of the order of 40 per cent. Thus, transport and communications, and electricity, gas and water supply, showed the smallest rises in labour costs over the period, and distribution and building and contracting, the largest.

It is explained in the survey that the increases in labour costs in the six-year period 1948 to 1954 were concentrated mainly in the years 1950 to 1952. Retail prices were forced up by the post-Korean rise in import prices and wages rose in pursuit. The Treasury adds that, in the different sectors of the economy, various factors have contributed in differing degrees to the changes in output. Among these have been increases in the labour force, larger capital investment, and the growth in productivity resulting from higher investment and more effective work.

Wages and Work

In his chairman's address at the annual meeting of United Dominions Trust, Ltd., which was held in London last Tuesday, Mr. J. Gibson Jarvie commented on several aspects of current industrial and economic affairs. He made particular reference to the "persistent demands for more pay without reference to output."

Mr. Gibson Jarvie recalled that at the recent conference of the Confederation of Shipbuilding and Engineering Unions, there was a unanimous resolution calling for an unspecified "substantial" increase in wages. In addition, he remarked, it was decided to press for the immediate reduction of weekly working hours from forty-four to forty without loss of pay, an annual holiday of three weeks with pay instead of two, and a ceiling on overtime of twenty hours a month. It was estimated, Mr. Gibson Jarvie continued, that for the unions involved this would cost approximately £100 million annually in wages, and that if all necessary work over forty hours a week was done on overtime, the annual cost would go up by another £30,000,000. It was perhaps germane, he commented, to remind ourselves that last March an increase in wages to these same men cost £70,000,000 a year. Could even the unions, Mr. Gibson Jarvie asked, have found a more inappropriate time for their new demands?

In another part of his address, Mr. Gibson Jarvie deplored the "great lack of realism" about the many social and economic problems facing us "at this serious time in our lives." The Government, he asserted, must take the first steps toward a more realistic outlook; taxation must bear an economic relationship to the national income. Mr. Gibson Jarvie went on to say that the strike weapon must give way to a more sensible method of settling industrial disputes, and for that the responsibility rested partly with the Government and partly with the trade unions. Some union leaders, he observed, showed that they recognised the position, but they would have to regain control of their members. Without more effective leadership, the unions were not likely to survive the growing practice of members capriciously to break their contracts; the measure of full employment must not include idle or half employed "workers" still drawing full employment pay. Wage increases, Mr. Gibson Jarvie added, must come only from increased economic production; the wage must be related to the price for the job, and that would be determined by world prices. The suspicion and antagonism of men towards their employers must be eliminated, Mr. Gibson Jarvie declared, and a man must be free to do another man's work if expediency or economic necessity demanded it. To make Great Britain strong and prosperous again need not be difficult; all that was required was a national and earnest approach to work and personal responsibility.

Coal Mining Statistics

Last week the National Coal Board issued a statistical statement showing the costs of production and proceeds from its collieries and other undertakings in the first quarter of this year. In that period the saleable tonnage from National Coal Board mines amounted to 54,918,429 tons, the quantity disposed of commercially being 51,006,268 tons.

The total costs of production in the quarter were £173,608,746 and the total proceeds £178,633,218, so that the profit from the mines, before charging interest, was £5,024,472. To this latter figure there was added £375,000 as the estimated profit on opencast working and £500,000 representing the profit from ancillary undertakings, making a total profit of £5,899,472. The loss on imported coal, however, amounting to £5,200,000, was the highest charge which had to be set against the operating profits, and in addition there was a figure of £5,150,000 representing the interest payable to the Minister of Fuel and Power. The final result, therefore, was a deficit for the quarter estimated at £4,595,528.

Of the total of £173,608,746 shown in the statement as production costs, the principal item is £107,477,896 required for wages, including holiday pay and allowances in kind. The average weekly cash earnings of all workers during the quarter were £12 11s. 8d., the average cash earnings of face workers being £14 11s. 1d. a week.

Production Planning and Control

The University of Birmingham has made arrangements for a residential executive course on "Production Planning and Control," to be held at the Institute for Engineering Production from September 26th to October 7th. It is stated that the aim of the course will be to discuss methods of production planning and control and the application of systematic analysis and study to these methods. Emphasis will be given to such matters as simplifying and improving procedures and systems of production planning; ensuring better integration of and co-ordination between production control and other management functions, and improving plant, material and labour utilisation, thus securing reductions of work in progress and operating costs.

The course is intended for industrial executives and senior production engineers and controllers. A similar course will be held from November 14th to 25th. Particulars may be obtained from the Institute for Engineering Production (University of Birmingham), 16, Norfolk Road, Edgbaston, Birmingham, 15.

Industrial Building

The Board of Trade has published recently a survey of industrial building for manufacturing industry in Great Britain since 1945. It states that in the ten-year period, from the end of the war, more than 10,000 industrial building schemes, representing an aggregate floor space of over 225,000,000 square feet, have been completed in this country. In much the same period—January 1, 1945, to June 30, 1955—approval was given to 18,207 schemes, representing a floor space of 459,350,000 square feet, and on March 31st last there were 2192 industrial buildings under construction. The survey also shows that about one-third of the industrial building completed before the end of last year was for the metal-using industries, i.e. mechanical and electrical engineering establishments, electrical goods factories, and vehicle and other metal goods factories. Of the remainder, 15 per cent was for the chemical, oil refining and allied industries, and just over 11 per cent for basic metal manufacturing.

Babcock and Wilcox Research Centre at Alliance, Ohio

No. II—(*Concluded from page 277, August 19th*)

Most of the research and development work conducted by the Babcock and Wilcox Company in the fields of thermodynamics, metallurgy, ceramics, physics and chemistry has now been concentrated in a research centre at Alliance, Ohio. Having started with one building in 1947, the centre to-day comprises eleven buildings and employs a staff of 350. This article describes the establishment and reviews certain major developments, particularly in the fields of super-critical boilers, fuel burning, metallurgy, refractories and atomic energy.

Steam Purity

STEAM purity is an important phase of the research work in the field of steam generation. For qualitative determinations the laboratory uses test equipment simulating a section of a 54in diameter steam and water drum, and uses air and water to simulate steam and water. The research centre has developed apparatus which produces steam in actual practice of a guaranteed purity of total solids not to exceed 1 p.p.m. At this point, however, the staff found itself beyond what could be tested accurately in this type of apparatus, designed to operate on steam at 125 lb per square inch gauge. As an illustration of the work which can be accomplished with this latest apparatus in the determination of steam purity with different modifications of separators under development, it is of interest to refer to radioactive tracer tests. One-half Curie of radioactive phosphorus P^{32} in the form of phosphate was added to the boiler water, and the magnitude of mechanical carry-over, expressed as per cent moisture, was determined by calculating the ratio of the activity of the condensed steam samples to that of the boiler water samples. The measured carry-over for the separating equipment tested was in the order of 0·0001 to 0·001 per cent moisture. These results indicate that a boiler having separating equipment such as that under test and having 1000 p.p.m. solids in the boiler water, would produce steam containing not more than 0·01 p.p.m. solids within the capacity range of the separator. Thus, for the first time in the history of steam sampling, it is believed, all of the steam is condensed, which eliminates the uncertainties and inaccuracies in ootaining satisfactory samples of steam for solids determinations.

At present the most common cause of turbine deposits in America is the selective carry-over of silica in vapour form. Appreciating this fact, the research centre undertook a test programme, which has just been completed, to determine the amount of selective silica carry-over that could be expected over the full pressure range of modern boiler operation. Tests were made in a small natural-separation boiler over a pressure range of 300 lb per square inch gauge to 3140 lb per square inch gauge, and it was determined that at any given pressure and boiler water pH the ratio of silica concentration in steam to that in boiler water was constant. This distribution ratio increases very rapidly with pressure, which explains the increased silica deposit difficulties experienced as operating pressures increase. Here, again, the laboratory used a radioactive isotope tracer technique for the determination of mechanical carry-over.

The fact that silica is distributed between steam and water in a definite ratio and that the solubility of silica in the water is many times higher than in the steam indicates that the most practical methods of reducing silica carry-over is by steam washing. By this method silica-laden steam is intimately contacted by condensate or feed water having a low silica concentration, and silica is absorbed from the steam by the wash water until the ratio of the steam and water silica concentrations approaches the distribution ratio. Steam washers are not particularly new, but the real problem involved in steam washing in a boiler drum lies in the degree of efficiency with which the washing can be accomplished in the limited space available. Steam washers utilising this principle were developed in a series of field tests in which more than twenty washer designs were tested, and in which as much as 85 per cent of the silica in the steam was removed. It is now felt that the use of such washers in high-pressure boilers will minimise silica deposits in the turbines and will allow higher silica concentrations in the boiler water without turbine fouling. In super-critical pressure boilers having no steam drum or separating equipment, steam purification cannot be provided for in the boiler proper, and the purity must, therefore, be inherent in the feed water used. Work on steam at super-critical pressures has, therefore, to a large degree, been concentrated on the means for producing water of a high degree of purity as well as means for measuring the small quantities of impurities involved. For example, in order to obtain accurate results with water of such purity, it was found necessary to evaporate 13 gallons of the water without external contamination over a period of about seven days in order to ootain a sufficiently large sample to measure the small quantities of impurities involved. The results indicated a silica content of less than 0·025 p.p.m., while the iron content was less than 0·010 p.p.m.

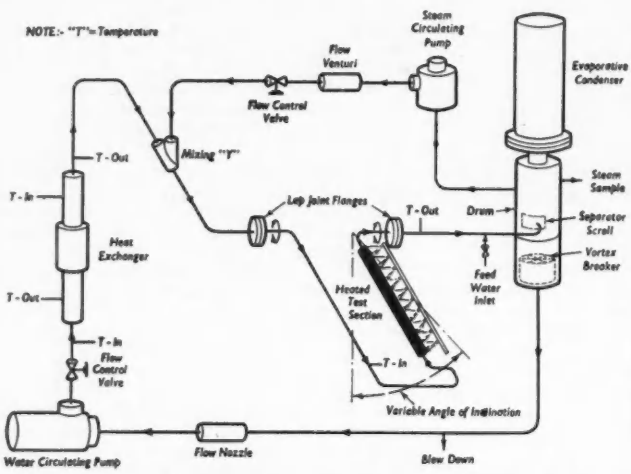


Fig. 5— Schematic diagram of below-critical-pressure test apparatus with variable inclination tube section

High-Pressure Boilers

High-pressure boiler design, whether based on natural or forced flow circulation, involves questions of limiting velocities of steam and water, steam percentage by volume, and rate of heat input to which the tubes are subjected. Operation outside the permissible limits can result in flow stratification with resultant corrosion and slow failure of the tubes, or overheating of the tube which can result in a short-time failure. To establish the limiting factors involved more definitely than had hitherto been known, the research centre set up an apparatus which is shown diagrammatically in Fig. 5. This apparatus permits variations in steam and water percentages by volume, operating pressures, velocities, heat inputs, and also the angle of inclination of the tube under test (Fig. 6), so that the staff can simulate in the laboratory the operation of a boiler tube at any possible place in a boiler. From this equipment, which is still under test, the company has been able to establish very definitely many of the limiting factors involved in operation at pressures up to the critical. These data are now in use in general boiler design and will be supplemented by additional data as they are obtained. As the indication of flow stratification is detected by a fluctuating temperature of a depth thermo-couple in the wall of the tube under test, it is important that this be determined immediately. The Bailey meter high-speed temperature indicator and recorder, which is used in connection with this test, has been found to be sufficiently fast in operation to show very clearly such fluctuations which might occur at the rate of thirty per minute.

The characteristics of a typical boiler tube failure caused by exceeding the limitations of the water-steam ratio have now been verified several times by means of the test loop. It has been shown that cyclic temperature variation occurs at these limiting conditions, causing the loss of the normally protective coating of iron oxide on the inside surface of the tube. Rapid loss of metal has resulted from this phenomenon, even at metal temperatures below 800 deg. Fah. The data show that the effect of angle of inclination is significant. The curves for the limits of flow stratification show a discontinuity which indicates that there may be two distinct laws governing the velocity limitations at high pressures. Factors involved in this failure problem on which the test loop data have already shed light include the minimum tube angle under certain conditions; pressure limitations on the boiler for given tube angles; maximum heat input limits and flow stratification limits. As the test loop equipment is constructed so that no matter what position a tube is in the heat is always in the same relation to the tube, this means that the heat energy striking the tube always does so in the same way, from the same source, in the same fixed positional relationship to the tube. This simplifies the study of other variables by eliminating any changes due to altered relationships between the heat and the tube. The test equipment makes it possible to vary the amount of water, the water temperature, the percentage of steam by volume, and—with a steam pump—it permits the entrance of a steam-water mixture. Many variables remain to be studied and it is planned in the immediate future to (1) extend the data, through the use of a steam pump and increased heat input, for further investigation of the discontinuities in the limits-of-flow-stratification curves and for the segregation of the effects of local heat input and angle; (2) investigate the effect of tube diameter on flow stratification limits; (3) obtain data with heat applied only to the top half of the tube, similar to the conditions existing in furnace floors and sloped walls; (4) determine the limiting heat flux to sub-cooled water, and (5) study the effect of feedwater chemistry.

Dealing specifically with super-critical pressure operation, in order to obtain answers to the many questions involved in going to this high operating pressure, the company installed a pilot installation at the laboratory, which is shown diagrammatically in Fig. 7. The natural gas fired boiler in this test apparatus (Fig. 8) consists of a single ¾in O.D., $\frac{1}{16}$in I.D., carbon steel tube, 400ft long, while the separately fired superheater consists of an alloy steel tube of the same dimensions, 100ft in length. The boiler has a capacity of 1200 lb of steam per hour and it is operated at 4500 lb per square inch gauge and 1150 deg. Fah.

Commercial steam generators of the future operating at pressures to 10,000 lb per square inch are foreseen by the Babcock and Wilcox Company on the basis of present knowledge and research. Work at the research centre has already resulted in the development of its first commercial unit to operate at above-critical pressures and temperatures and is now being built for the American Gas and Electric Corporation. It will be situated at the Philo Station of the Ohio Power Company and can operate at both above and below critical conditions. It is of the "once-through" design: water is pumped into it at one end and superheated steam is taken off at the other end. Water enters the inlet header at 5500 lb per square inch. To withstand these high pressures, and the high steam temperatures, the entire high-pressure side of the steam generator except the headers, is made up of small-diameter tubing of considerable thickness, varying in composition from carbon steel at the inlet to stainless steel at the outlet. As this is a "once-through" unit, there is no need for a drum and the usual height to provide separation of the steam and water and adequate circulation. The steam generator can thus be arranged in a very compact manner, resulting in an appreciable reduction in building volume. Investigations at the research centre, which have already resulted in the development of this commercial unit, are continuing. They are aimed at breaking further and further away from present conventional design limits in pressures and temperatures. Studies were made on the supercritical pilot unit with pressure-temperature conditions of 4500 lb per square inch and 1150 deg. Fah. at the superheater outlet. Heat transfer coefficients were obtained at pressures above the critical with steam flowing inside the tube. Film conductances were determined by resistance heating in which the tube material served as the electrical conductor. During the tests, fluid temperatures ranged from 200 deg. to 1000 deg. Fah., heat inputs from 150,000 to 600,000 B.Th.U. per hour per square foot of inside tube surface and pressures from 3500 lb to 4500 lb per square inch. Pressure drop determinations were made on all sections of the unit while operating at 5000 lb per square inch and 900 deg. Fah. at the superheater outlet.

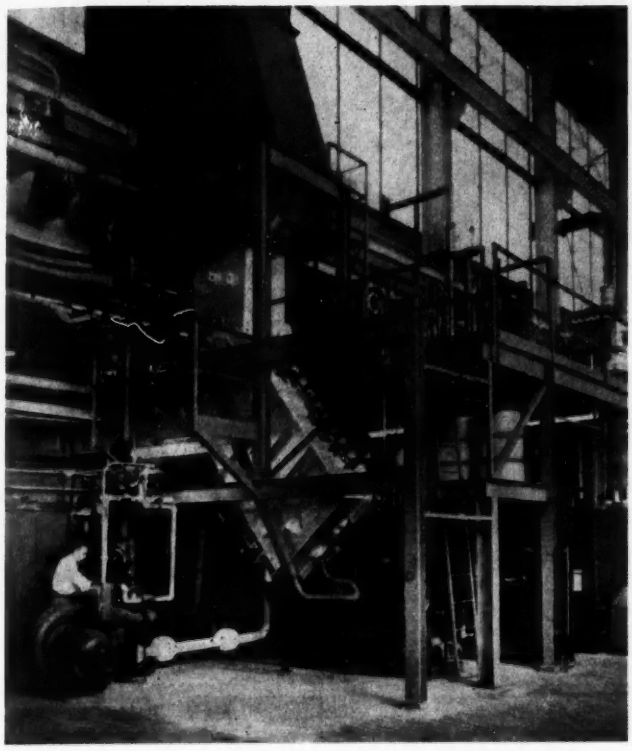


Fig. 6—Below-critical-pressure test unit showing tilted refractory furnace containing tube section

Proper water conditioning and control are considered to be basic factors for the successful continuous operation of a "once-through" steam generator, since in such a unit all solid impurities in the feedwater are available for deposition in either the steam generator or the turbine. Furthermore, operation under "once-through" conditions involves a transition of the fluid from the liquid to the gaseous phase within the heat-absorbing zone and the mechanisms of corrosion and solids deposition under these conditions have not heretofore been fully investigated. Therefore, extensive feedwater tests have been made at Alliance to determine boiler availability; the effectiveness of water washing as a means of removing iron deposits; the effectiveness of water washing as a means of removing the deposits which would result from condenser leakage; the effect of the 1150 deg. Fah. operating temperature, and to establish actual corrosion rates within the systems. In co-operation with the Bailey Meter Company, extensive response and control tests were run. The pilot plant was operated under various load conditions to determine its response and control characteristics, and served to illustrate that there are no unusual control problems associated with an above-critical "once-through" unit.

Metallurgical Research

Metallurgy is of fundamental importance to research in the field of steam generation. The ultimate in efficiencies and economies is largely dependent upon the strength of metals to withstand both pressure and temperature, so that it is very natural that the company should be leaving no stone unturned in its search for improved metals to withstand the ever increasing demands in these directions. For materials or alloys for which high purity is essential, as, for instance, in applications for atomic energy, it is necessary to provide the utmost protection during the melting operation. In order to accomplish this the alloys are made from chemically pure materials and are melted in a vacuum induction furnace at an absolute pressure of not more than 500 microns Hg and down to 1 micron Hg. Melting operations for the development of the less critical "super-alloys" are performed in regular small size induction furnaces. Heats of 5 lb, 25 lb and 100 lb capacity can be melted so that normal steel melting practice can be approached as closely as is possible in a laboratory set-up and so that the resultant metals will be truly representative of high grade commercially obtainable products. The small ingots cast from the furnaces are then forged into test specimens, and subjected to standard mechanical tests. On the large 60,000 lb tensile testing machine an electrical resistance heating furnace can be installed around the test specimen to permit the tensile tests to be made under elevated temperature conditions. As most of the firm's work is concerned with the alloys in tubular form it is found useful to employ a small tensometer in which specimens taken from a tube wall, for example, can be subjected to test. Here, again, the apparatus has been equipped with a small electrical resistance heating furnace so that the tests can be conducted under elevated temperature conditions. It is interesting to note that there is a remarkable degree of conformity of results between these two machines, particularly with ferritic materials.

Stress rupture determinations are made on multiple stress rupture machines. These machines, which were designed and built in the Laboratory, each accommodate twelve specimens, all of which are maintained at the same constant temperature. Different alloy specimens, or different specimens of the same alloy, can be loaded by weights to different degrees, and heated at different temperatures in different furnaces. As the specimens fail they can be replaced individually without interfering with the other specimens under test. Altogether the Creep Laboratory has 136 stations which are being employed with a use factor of 98·2 per cent. As mentioned previously, the company is primarily interested in these alloys in tubular form, and in order to simulate more nearly actual operating conditions the research centre devised, and is now operating, a tubular stress rupture apparatus. In this apparatus the ends of the full size tubular specimens are closed off and steam pressure maintained within the tubular specimen while it is subjected to external temperature at any desired level by means of electrical resistance heating coils. In this manner the laboratory can determine stress rupture characteristics under conditions simulating actual practice.

Most of the alloys at present under development at Alliance have iron, nickel and chromium as base metals. The company has found that a 15 per cent Cr-15 per cent Ni alloy is the leanest composition that still has an oxidation resistance high enough for service in superheater tubes in the newly desired temperature range. In developing alloys for high-temperature, high-pressure work, hundreds of heats are made up. For instance, in one programme alone 247 different melts were made up from these base metals, adding various elements to them to improve their performance Although chromium and nickel alloys resist oxidation, they cannot carry high loads at high temperatures without added elements. Thus, adding molybdenum, columbium or tantalum to the base elements has been found to give the alloy higher strength and greater load-carrying ability.

The design of thick-walled pressure vessels to withstand high temperatures is another important phase of the centre's work, and the selection of metals to be used, as well as the specific designs of drum openings and the like, frequently

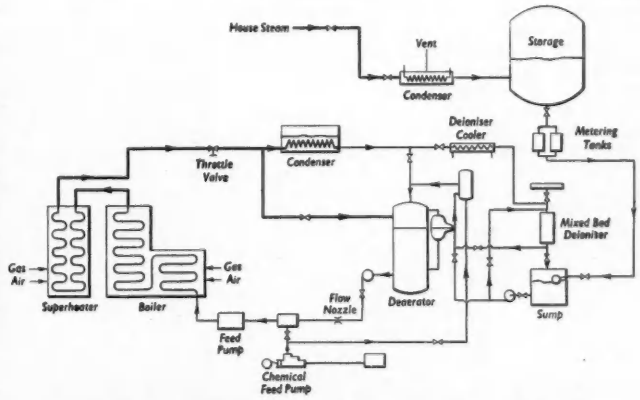


Fig. 7—Schematic diagram of super-critical-pressure test apparatus operating at 4500 lb per square inch gauge and 1500 deg. Fah.

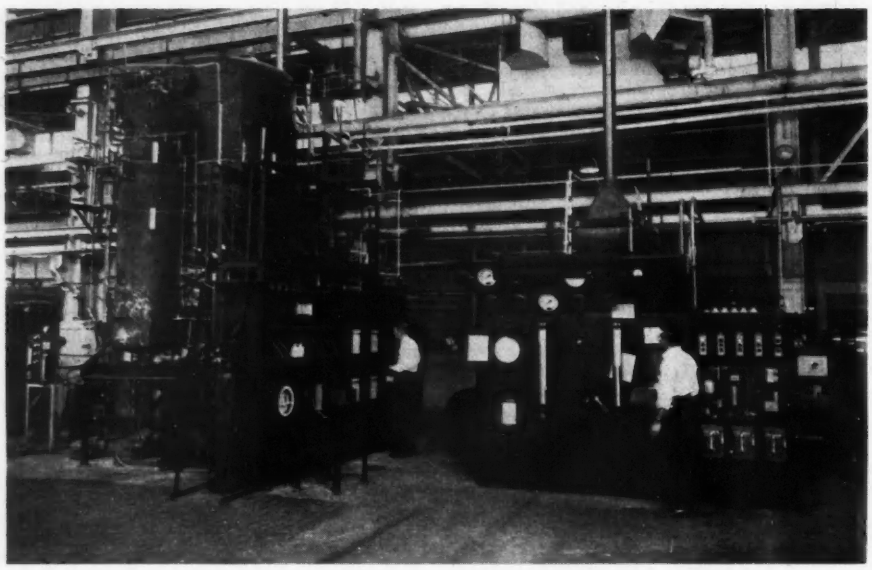


Fig. 8—Super-critical-pressure test unit for investigating " once-through " boiler operation

necessitate fatigue testing. With large test vessels this testing is done with a Pulsator fatigue testing machine, the vessel under test being situated within an enclosure provided by blasting mats which are used for general safety purposes. After the test vessel has been partially filled with paving brick to minimise the quantity of water in the vessel under pressure for test purposes, it is tied into the system consisting of a balancing vessel and a high pressure plunger. By this arrangement the plungers serve to transfer the pressure from one vessel to the other alternately, providing lower power operation than if the test vessel were used with a conventional pump. Such tests run for more than 100,000 cycles at the rate of 17 cycles per minute at pressures up to 6000 lb per square inch gauge to establish satisfactory performance of the vessels under test. This, however, is a large and cumbersome piece of apparatus, and the company recently devised a smaller and safer apparatus that can also be operated less expensively. This small bi-axial fatigue testing machine is operated by means of oil pressure. It has recently been adopted as a standard testing means by the Pressure Vessel Research Committee of the American Welding Society.

The development of alloys to withstand corrosion is another important field of research activity at the centre. The need for such metals is particularly great to-day for structural members such as superheater supports in oil-fired furnaces. Many of the available residual oils have high vanadium and nickel contents in their ash, and the various oxides of vanadium, especially the pentoxide V_2O_5, are particularly corrosive under high-temperature conditions. The laboratory is working on new alloys to withstand this corrosion problem and is using sample baskets of different alloys installed in oil-fired units at different temperature locations to test the various alloys under consideration. It has been found that when small quantities of dolomite are added to the oil fuel as burned, it has an appreciable effect on reducing the amount of corrosion that occurs. To date no satisfactory material has been found to withstand this corrosive condition, but the laboratory is actively continuing its investigations.

The laboratory is making considerable progress in welding techniques, and has recently developed a welding method by means of which the rate of weld metal deposition with the submerged arc welding process can be very materially increased. It is known as the I^2RT method, and is applicable to submerged arc welding, in which the bare electrode is fed through a layer of granular flux, and to inert gas shielded welding. Standard submerged-arc welding practices have been based on the principle that deposit rate is directly proportional to the diameter of the electrode. This theory holds true with flux-coated electrodes where current density is limited. However, the company found that desired weld patterns could be made at deposit rates that were inversely proportional to wire size for a given current. In one case, for example, a higher deposit rate was obtained with a $^3/_{32}$in diameter electrode at 650A than with a $\frac{1}{4}$in electrode at 800A. Experiments subsequently revealed that the deposit rate at high current density is directly proportional to the length of the electrode wire from the contact shoe to the arc. This discovery led to the I^2RT principle of submerged-arc welding. The new process preheats the electrode almost to its melting point before it enters the arc. Thus the arc does not have to supply the sensible heat required to bring the metal to the melting point, as it does in standard submerged-arc processes. Practically all the energy absorbed by the electrode at the arc supplies heat of fusion to melt the metal.

The energy required to heat the electrode to the melting point is measured in terms of the square of the current I^2, the resistance R of the electrode wire projecting from contact nozzle to arc, and the time T that the current flows through any given cross section of the wire.

The new welding technique uses higher current densities than existing welding methods. For example, the current density in the electrodes

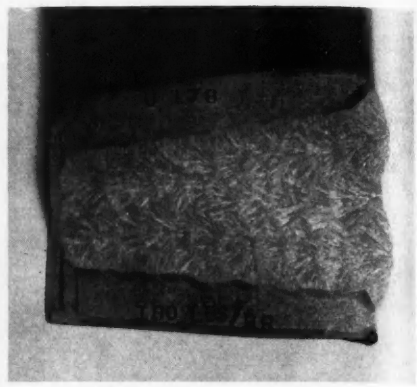


Fig. 10—Section of butt joint in 3in steel plate made by " I^2RT " welding process at a deposit rate of 180 lb per hour

varies from 70,000A to 270,000A per square inch, as compared with 10,000A to 20,000A per square inch using other methods. Only with submerged-arc welding and inert gas welding are these ranges possible, since such high current densities would damage flux-coated electrodes. The company is now using carbon-steel wire electrodes with tensile strengths of 70,000 lb per square inch for production work. Experiments, however, have been made with alloy steel electrodes. The electrical resistance of the alloy steels is higher, but, in principle, the I^2RT method will work with them as well as with the carbon steel electrodes. In operation, a voltage-sensitive relay controls the length of electrode projecting from the nozzle. Any changes in the load voltage are received by this relay, which signals the raising or lowering of the weld head. The granular flux, through which the wire is fed, is composed of finely divided metal oxides, and the flux depth is approximately 1in to $1\frac{1}{2}$in. To keep pace with the fast deposition of metal, a special guiding device has been developed which keeps the weld head and arc in line with the work. The beads are deposited too fast to allow accurate manual guiding.

Using a current of 1000A, I^2RT welding can deposit metal up to 100 lb per hour. Comparable commercial welding processes have been found to deposit only 30 lb per hour with the same current. In standard automatic welding systems, 80 per cent of the total heat is dissipated in melting the base plate and heating flux or is lost, and only 20 per cent is actually used to melt the electrode. With the new process, all I^2RT energy is applied directly in the electrode to heat the wire. Using only two and a half

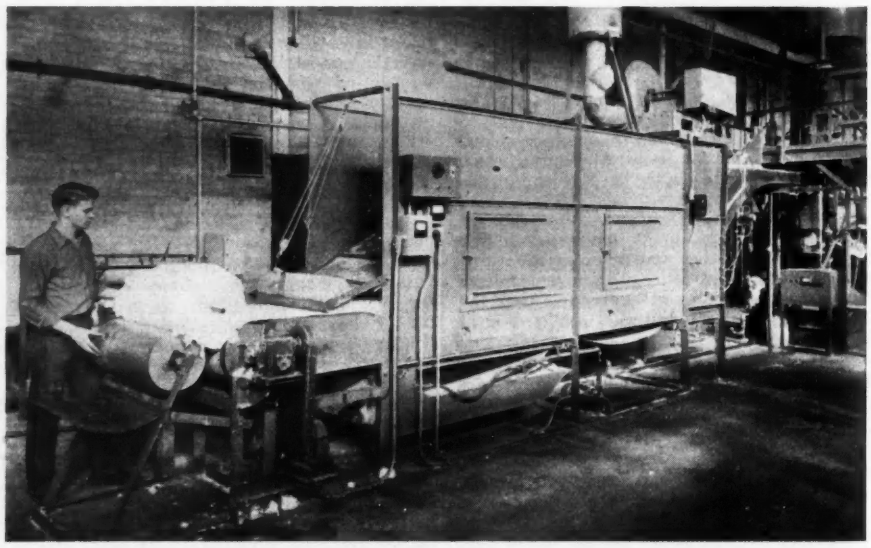


Fig. 9—Pilot plant for the production of " Kaowool " insulating refractory blankets

times as much energy as present welding processes the new technique can melt five times as much weld metal.

The conversion of existing welding equipment to I^2RT welding would consist mainly of installing suitable transformer capacity and increasing the rate of feeding the wire electrode. In some cases larger or additional transformers would be required, since the new process needs double the load voltage formerly required. Travel speeds of the equipment would also have to be increased.

The welding of dissimilar metals, such as ferritic to austenitic materials, in steam pipes and the like, has caused considerable trouble in the past, due primarily to the differences in the coefficients of expansion of the different metals. This results in stresses at the junction or weld following a number of temperature variations due to taking the system in and out of operation. These stresses have resulted in failures which usually occur at the ferritic side of the weld junction. To overcome this fault, the research centre has been working on the development of an alloy to be used for the weld metal that would be austenitic in character, but would have a coefficient of expansion very close to that of the ferritic material, and which would produce satisfactory, sound welds. The laboratory has been successful in developing an alloy which shows good promise of being able to accomplish this end, and a specimen is now being tested in which a number of sections of ferritic and austenitic pipe are welded together with test weld alloys for long-time examination. The availability of induction melting furnace, forging hammers, and wire drawing equipment at the research centre has greatly facilitated this development.

Refractory Fibres

In recent years, new uses have been found for "Kaowool," the firm's high-temperature refractory fibre, which promise to make this versatile product competitive with other long-fibre refractories and superfine glass fibres. An improved manufacturing process has been developed by the research centre to produce a long-fibred wool with no visible "shot" in it. The expected new uses for the improved product are in incinerators, turbine blankets, fire-resistant construction, household appliances and guided missiles. Currently "Kaowool" is being used as an insulating blanket in the after burners and tailpipes of jet engines, where it is said to withstand temperatures up to 2000 deg. Fah. indefinitely. The material is also being tried out as insulation in lorries and cars, filling for life preservers, reinforcement for plastics and as a resilient packing for kilns, hot-air ducting and annealing ovens. The company is now producing "Kaowool" at its research centre in the form of a tough resilient blanket. No organic binder is used to hold this blanket together. Hence, the blanket retains its full strength and coherence at much higher temperatures than other high-temperature refractory blankets. In this form, "Kaowool" can be successfully hung inside an enclosure without settling and without needing to be sandwiched between retaining walls.

"Kaowool" is a pure white homogeneous fibre made by melting and blowing kaolin, the clay from which it takes its name. The material does not melt below 3200 deg. Fah, and as a fibre, can withstand temperatures up to 2000 deg. Fah., without change or loss of resiliency. It thus surpasses standard glass wools, which begin to deteriorate at 1000 deg. Fah., and rock wool, which is only effective up to about 1200 deg. Fah. To make the fibre, kaolin clay is first electrically melted. The molten material then streams through a tapping nozzle and is blown into fibres. The processed "Kaowool" is then collected on a pad-forming conveyor. Initially, "Kaowool" was produced only in bulk form. A technique for blowing fibres into lengths of eight inches or longer, which uses high-pressure air, made the manufacture of the blanket possible. Besides lengthening the fibre, the new process has reduced the individual fibre diameters to about 3 microns, or about $^1/_{20}$ the diameter of a human hair. Such small fibres are particularly desirable for improving the insulating value at all temperatures and to give the material a soft, cotton-like texture. The laboratory has developed an improved blowing nozzle that has considerably reduced the shot content of "Kaowool" to where it can no longer be seen in the material. The "blown quantity" of the material is now believed to be equal to that of competitive wools, which must undergo expensive cleaning operations. Besides being costly, cleaning operations tend to weaken or break down the long fibres of the wool. Short fibres do not lend themselves to fabrication as a blanket. For example, the fibres of other aluminium silicate wools are too short to make a satisfactory blanket except by addition of an organic binder which burns out in use. On the other hand, the long fibres obtained by acid leaching glass to pure silica make the fibres weak, brittle and dusty besides being expensive. The material is now being turned out by a pilot plant at the rate of 1000 lb a day. A full-size plant is a distinct possibility, and as a result of recent experiments, the company feels that the present process can easily be adapted to large scale production.

At the research centre, the company is also studying the thermal conductivity of "Kaowool" for both high and low-temperature applications. Inasmuch as the orientation and uniform density of the wool greatly affect its high-temperature conductivity, the blowing duct and pad-forming conveyor are currently being improved to provide this better orientation and distribution of the fibres. The laboratory is also testing improved melting processes that do not require the use of a carbon arc, which is relatively expensive and presents certain operating problems. Other tests including bulk density determination, X-ray analysis for crystallisation and microscopic diameter measurement, are being performed on "Kaowool." A reproducible and rapid method of determining shot content has been devised and is now used for quality control.

New Jersey Turnpike Extension Over Newark Bay

The accompanying illustrations show the current progress of construction of the Newark Bay bridge, which is being erected by the Bethlehem Steel Company for the New Jersey Turnpike Authority. With the completion of the approach girder spans only the continuous tied arch central span of the bridge, with an overall length of 1270ft and providing a vertical clearance of 135ft above water at the channel, remains to be finished. The 4057ft long east approach of the structure leads to Bayonne and Jersey City and will give these neighbouring cities a rapid and long-needed highway connection with communities in Essex and Union Counties, as well as with the Newark Airport. The big east approach girders, 170ft long and 11ft 6in deep, were fabricated at the Pottstown Works of the Bethlehem Steel Company and were transported to the Bayonne peninsula by rail. There the flat wagons with girders were placed on floats and towed to the erection site by tug, since most of the east approach is built over water. The girders were erected by a large traveller crane with two 115-ton derricks, which placed the girders in their permanent position on top of the 127ft high concrete piers.

Fig. 2—Western approach span of Newark Bay bridge

Our illustrations show an unusually large concentration of heavy construction equipment assembled at the construction site. The two-derrick traveller crane was at work on the east approach. The two smaller traveller cranes, with one derrick apiece, were erecting the arch span, and a tower derrick crane boat with a 138ft high tower topped by a 35-ton stiffleg derrick was removing falsework which had been set up on piles to get the arch span started. The bridge, which is being built by the New Jersey Turnpike Authority, is part of an 8-mile extension of the turnpike leading from the Newark Airport "interchange" to the Holland Tunnel. It will thus provide a new and direct route from Manhattan to the airport and the metropolitan New Jersey areas. With its approaches the bridge is 9560ft long and contains over 25,000 tons of steel. Bethlehem, the superstructure contractor, is also erecting another 11,000 tons of steelwork for a viaduct connecting the west approach of the bridge with the airport "interchange" of the turnpike.

Fig. 1—Central arch span of Newark Bay bridge under construction

Personal and Business

Appointments

MR. WILLIAM PAYNTER has been appointed works manager of Mervyn Instruments, St. John's, Woking, Surrey.

HEAT EXCHANGERS, Ltd., states that Mr. G. D. Toogood, A.M.I.Mech.E., general manager, has been appointed a director.

BRITISH INSULATED CALLENDER'S CABLES, Ltd., announces the appointment of Mr. E. Watt as manager of the Chester branch.

MR. J. A. BROUGHALL, M.I.E.E., has been appointed electrical engineer (development) on the central staff of British Railways.

SHARPLES CENTRIFUGES, Ltd., announces the appointment of Mr. G. G. Jackson as a chemical engineer at the Tower House Laboratories, Stroud.

MR. DEREK O. THURGOOD has been appointed to the publicity department of the Fairey Aviation Company, Ltd., 24, Bruton Street, London, W.1.

MR. GILBERT DODD has been appointed a director of Monsanto Plastics, Ltd. He has been general manager of the company since its formation in 1953.

D. NAPIER AND SON, Ltd., Acton, London, W.3, announces the appointment of Group Captain B. H. Becker as technical manager, turbo-propellers.

MR. D. KINNELL has been appointed sales manager of Dorman and Smith, Ltd., and D. S. Plugs, Ltd., on the retirement of Mr. C. M. Nesbitt from the position of sales director.

MR. D. J. BOLTON, M.I.E.E., is joining the consulting staff of Messrs. Kennedy and Donkin on his retirement from the commercial department of the Central Electricity Authority.

MR. P. T. HEADY has been appointed a member of the London Midland area board, and Mr. J. MacNaughton Sidey, a member of the Southern area board, of the British Transport Commission.

THE WIDNES FOUNDRY AND ENGINEERING COMPANY, Ltd., states that Mr. A. Whitfield, production manager, and Mr. H. L. Sanders, chief draughtsman and designer, have been appointed to the board of directors.

THE MINISTRY OF SUPPLY announces the following appointments: Mr. J. E. P. Dunning, director of engine research and development; Mr. R. O. Freeman, director of guided weapons production; Mr. R. J. Lees, director of scientific research, guided weapons.

MR. G. A. WILSON, M.I.C.E., M.I.Mech.E., chief engineer of the Port of London Authority, has been appointed to succeed the late Sir Athol Anderson, K.C.B., as one of the British nominees on the International Consultative Works Commission of the Suez Canal.

THE ENGLISH ELECTRIC COMPANY, Ltd., announces the appointment of Mr. W. Plumb as deputy commercial manager of the Liverpool and Netherton works. For the past six years Mr. Plumb has been manager of the Leeds branch office. His successor there is Mr. A. J. Evans.

THE BRITISH TRANSPORT COMMISSION has announced the appointment of Mr. William Jeffers as chief docks manager, South Wales docks, with headquarters at Cardiff. He succeeds Mr. H. E. H. Brown, who was recently appointed general manager of the Scottish Region of British Railways.

F. PERKINS, Ltd., Peterborough, announces the following appointments in its engineering division:—Mr. J. R. Condie, manager of the design department; Mr. J. G. Dawson, A.M.I.Mech.E., manager of the experimental department, with Mr. M. Vulliamy, A.M.I.Mech.E., continuing as chief experimental engineer; Mr. W. Spoor, A.M.I. Mech.E., assistant to Mr. M. I. Prichard, director of the engineering division.

THE LONDON MIDLAND REGION OF BRITISH RAILWAYS announces the appointment of Mr. R. L. McIlmoyle, M.I.C.E., as assistant civil engineer (modernisation). Since 1949 he has been assistant engineer (new works). Mr. C. G. Derbyshire has been appointed assistant signal engineer (modernisation). He has been divisional signal and telecommunications engineer at Manchester since 1948, in which position he will be succeeded by Mr. D. S. Jewell.

Business Announcements

GEORGE ELLISON, Ltd., and TUFNOL, Ltd., Perry Barr, Birmingham, state that in future their sales and engineering service in Canada will be handled by the Electric Construction Co., Canada, Ltd., 1947, Avenue Road, Toronto, 12.

THE BIRMINGHAM SMALL ARMS COMPANY, Ltd., is taking over a Northern Ireland Government factory at Carnmorney, near Belfast.

BIRMINGHAM SOUND REPRODUCERS, Ltd., is to occupy a factory at Pennyburn, Londonderry, which is under construction by the Northern Ireland Ministry of Commerce.

LANCASHIRE DYNAMO HOLDINGS, Ltd., announces the formation of a new company in Australia entitled Lancashire Dynamo Coates Pty., Ltd. The head office of the company is in Melbourne.

ALBRIGHT AND WILSON, Ltd., 49, Park Lane, London, W.1, states that it has signed an agreement with the General American Transportation Corporation for developing the "Kanigen" process of chemical nickel plating. Albright and Wilson, Ltd., will become the sole licensees for the process in the United Kingdom, Eire and Denmark.

Contracts

VICKERS-ARMSTRONGS (SHIPBUILDERS), Ltd., has received an order from the Esso Petroleum Company, Ltd., for two new tankers, each of 36,000 tons deadweight to be built at the Naval Yard, Walker-on-Tyne. The propelling machinery will be constructed by Vickers-Armstrongs (Engineers), Ltd., Barrow-in-Furness. The dimensions of the tankers are: length between perpendiculars, 660ft; breadth moulded, 90ft; and depth moulded to upper deck, 47ft.

Miscellanea

BULLETIN ON TITANIUM.—We have received from Imperial Chemical Industries, Ltd., a copy of the first number of a bulletin containing abstracts of published information concerning titanium. It is intended to issue the bulletin every month.

SAFETY IN MINES.—The Ministry of Fuel and Power has issued, through H.M. Stationery Office, a supplement to the 1953 edition of *Regulations and Orders Relating to Safety and Health*. It sets out all the additions which have been made since December, 1952, to the statutory regulations concerning safety and health in coal mines. It does not, however, deal with the provisions of the Mines and Quarries Act, 1954. When these become effective a complete revision of the 1953 volume of *Regulations and Orders* will, of course, be made.

STRESS ANALYSIS CONFERENCE.—The Institute of Physics says that the ninth annual conference of its stress analysis group is to be held from September 28th to 30th at Stephenson Hall, University of Sheffield. It will take the form of a general conference on the applications of stress analysis. The papers to be presented include some from foreign visitors, and arrangements have been made for visits to local laboratories and works. Further particulars of the conference may be obtained from the Institute of Physics, 47, Belgrave Square, London, S.W.1.

CONFERENCE ON PRODUCTION MANAGEMENT.—The Society of Industrial Engineers has announced that it is arranging a conference, in association with the Work Study Society, on the subject of "Aids to Effective Production Management." This conference will be held at St. Ermins Hotel, Westminster, London, S.W.1, on November 4th and 5th, the principal aim being to emphasise the value of work study data for the planning and control of output and costs. Full details are available from the Society of Industrial Engineers, 28, Victoria Street, London, S.W.1.

RAPID-HARDENING REFRACTORY CEMENT.—A white calcium aluminate hydraulic cement recently introduced to this country by Lafarge Aluminous Cement Company, Ltd., 73, Brook Street, London, W.1, is claimed to extend the range of refractory properties possible with ciment fondu. The new cement, Secar 250, when mixed with corundum aggregate, can work up to 1800 deg. Cent, and various other refractory aggregates can be used. Concretes made with this cement can all be put into service within twenty-four hours of casting, do not shrink, and have a high resistance to thermal shock.

SCHOOL IN HIGHWAY ENGINEERING AT BIRMINGHAM.—The civil engineering department of the University of Birmingham is proposing to hold a two-weeks' school in highway engineering between September 12 and 24, 1955. This course is being arranged with the support of the Paviors Company. The lectures dealing with traffic and safety and the construction of roads will be given by a team of lecturers from various organisations, each of whom is considered to be a specialist in his subject. Some foreign engineers with experience in the design and construction of motor roads will also lecture.

L.C.C. EVENING CLASSES.—The London County Council has issued the latest edition of its annual publication entitled *Floodlight*, which gives particulars of the evening classes available in the year beginning September. There are details of many courses in engineering and related subjects, special emphasis this year being given to such matters as astronomy and atomic power, industrial experimentation and control techniques, electronics, time and motion study, industrial relations, management studies, and foremanship. Enrolment week for all the classes at L.C.C. evening schools and institutes begins on September 19th.

LOW-COST LABORATORY APPARATUS.—The United Nations Educational Scientific and Cultural Organisation has now published the second series in its set of drawings' "The Construction of Laboratory Apparatus for Schools," in French and English, price 45s. The equipment covered is designed to be mass produced at perhaps one-third of the cost of conventional apparatus and is also designed to stand up to tropical conditions. The designs are intended for countries with a shortage of science teaching equipment and of foreign exchange, but possessing craftsmen and vocational schools adequate for the manufacture of apparatus.

IMPORTS OF COPPER WIRE RODS.—Last February, the Board of Trade announced that a quota of 7500 tons per annum had been established for the import of black hot-rolled copper wire rods from Canada and the U.S.A. during the year beginning April 1, 1955. The quota was to be allocated in two half-yearly instalments. Agents of North American producers of rods and wire drawers in the United Kingdom are now invited to apply for licences to import during the second period and applications should be submitted on form ILB/A to the import licensing branch of the Board of Trade, 43, Marsham Street, London, S.W.1, not later than September 1st.

CAVITATION IN HYDRODYNAMICS.—A symposium on "Cavitation in Hydrodynamics" is to be presented at the National Physical Laboratory, Teddington, on Wednesday, Thursday and Friday, September 14th, 15th and 16th. An opening address entitled "A Critical Review of Recent Progress in Cavitation Research" will be delivered by Mr. P. Eisenberg, of the United States Office of Naval Research, at 11.30 a.m. on September 14th, and in the afternoon of that day the papers to be discussed will deal with "Factors Governing Cavitation Inception." On September 15th papers will be presented on experiment techniques and scale effect factors, and on the final day of the symposium the subjects to be dealt with are "Effects on Hydrodynamic Performance" and "Cavitation Damage."

HOSE FOR SULPHURIC ACID.—The Flexibles Advisory Service of the Compoflex Company, Ltd., 26, Grosvenor Gardens, London, S.W.1, announces a new flexible hose for carrying concentrated sulphuric acid. On test the hose has carried sulphuric acid of 77 to 94 per cent concentration, the acid being at pressures up to 22 lb per square inch and temperatures ranging from 33 deg. to 40 deg. Cent. It is claimed that the hose can be used for hydrochloric, formic, citric, phosphoric 98 per cent, and lactic acids, caustic soda and vegetable oils. The hose, which is available in bore sizes up to 4in, consists of a stainless steel wire helix, an inner liner of molene coat glass cloth, plies of polythene sheeting, a layer of untreated glass cloth, an outer cover of acid and abrasion resistant PVC and a spiral of mild steel wire.

TRUNK ROAD IN INVERNESS.—The North of Scotland Hydro-Electric Board has given details of a new main trunk road, 8 miles long, between Glen Garry and Glen Moriston, Inverness-shire, in its Constructional Scheme No. 23C, Moriston Project. The Board's Glen Moriston scheme involves the raising of Loch Loyne, which lies between Glen Garry and Glen Moriston. It was originally proposed to carry the Glen Garry/Glen Moriston trunk road across the loch on a viaduct about ¾ mile in length, but a later proposal was that the part of the road between Cluanie Inn and Loch Loyne should be abandoned and that a new road, less likely to be snowbound, should be substituted, running along the southern shore of Loch Loyne and down to the main road in Glen Moriston. The Ministry of Transport favoured the second alternative and the proposed amendment is incorporated in the new scheme that the new road will leave the Loch Garry road near Achaluachrach, about 2 miles from the eastern end of the loch and climb gradually over to Loch Loyne to join the Glen Moriston road at Bunloyne, near the eastern end of Loch Cluanie. The carriageway will be 11ft wide, increasing to 18ft at passing places, and bridges will be 23ft between parapets.

British Patent Specifications

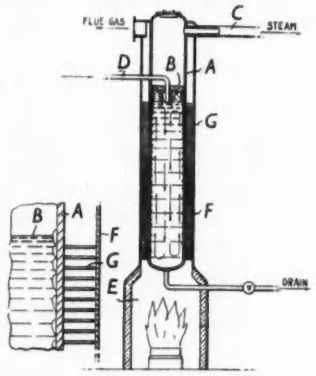
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2. 3s. each.

STEAM GENERATORS

734,169. October 7, 1953.—APPARATUS FOR GENERATING STEAM, AB Svenska Maskinverken, Sodertalje, Sweden.

The invention has as its purpose to improve the generation of steam so that a small compact plant will have a capacity equivalent to that of a much larger plant with dry steam obtainable directly from a boiler. Referring to the drawing *A* represents a closed upright vessel in which a supply of water is maintained to a level *B* spaced a distance below the steam outlet *C* near the closed top of the vessel. The water is supplied to the vessel through an inlet pipe *D*. The vessel is mounted above a combustion chamber *E*. The hot gases flow up over the outside of the vessel, being confined in their passage by an outer casing *F* which forms in effect a continuation of the combustion

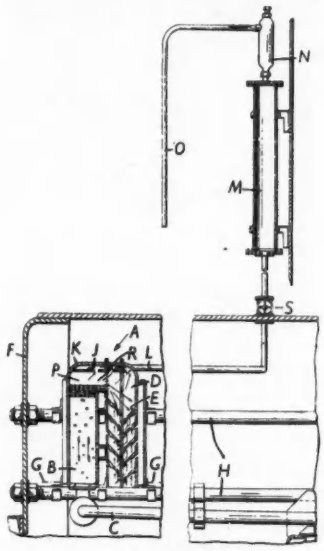


No. 734,169

chamber. The outer surface of the vessel *A* is equipped with extended surface *G* in the form of rod-like pins or wires of the type illustrated in the Dalin Patents Nos. 673,721 and 715,611. As shown, these extended surface elements extend substantially entirely across the space between the vessel and the casing, so that the hot flue gases must contact the extended surface in its passage to the outlet. With correct proportioning, arrangement and disposition of the extended surface elements, heat energy abstracted from the heating medium is transferred to the water in the vessel at such a rate that the temperature of the gases, upon reaching the upper portion of the vessel which provides the steam space, is low enough to be incapable of deleteriously effecting these relatively dry surfaces. By virtue of this rapid heat transfer the water in the vessel contiguous to its upright wall is quickly generated into steam and the resulting steam bubbles rise rapidly and freely over the inner surface of the vessel wall to enter the steam space as shown without appreciably disturbing the surface of the water, and accordingly the steam is far drier than that produced by present methods, containing not more than about 0·3 per cent. moisture. Tests have established that a single unit, such as shown in the drawing, having the following dimensions :—Inside diameter, 6·5in ; wall thickness, ¼in ; overall height of vessel, 38in ; extended surface on lower 26in of side wall, produced 300 lb of dry saturated steam at 180 lb per square inch per hour. Designs for a marine boiler and other steam generating plants are also shown in the specification.—*July* 27, 1955.

734,283. June 24, 1952.—INTERNAL FEED-WATER DEVICES, Ernest McMaster, M.I.Mar.E., 58–68, Tomb Street, Belfast, Northern Ireland.

The invention relates to internal feed-water de-aerating devices for steam generators, also described in Specification No. 482,878. The device *A* consists of a preheating chamber *B* to which water is fed through a pipe *C*. At its upper end, the chamber is in communication with a second chamber *D* having a series of slotted plates *E* and through which the water from the chamber *B* passes into the boiler *F*, the water level in the latter being indicated at *G*. The chambers *B* and *D* are suitably supported on the longitudinal stays *H* of the boiler *F*. In Specification 482,878, the passage *J* at the top of the device is open at its outer end *K* so that air may escape into the boiler *F*. In the present invention, the vent passage *J* at the top of the device is closed at its outer end *K* so that the device at the top is completely closed to the steam space of the boiler. The passage *J* intermediate its ends is, however, connected to one end of a pipe *L* which extends with a gradual rise longitudinally of the boiler through its steam space and then passes upwards through the wall of the boiler at the top. The upper end of the pipe *L* is connected to the lower end of a vertical cylindrical vessel *M* which is closed at both ends. To the upper end of the vessel there is attached the inlet side of a thermostatically controlled air-release valve *N*, the outlet side being connected to a discharge pipe *O* communicating with the atmosphere. In operation, steam and air from the feed water passing through

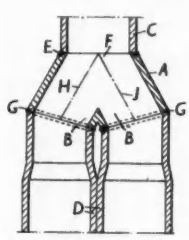


No. 734,283

the device *A* pass up into the passage *J* through the pipe *L* and up into the vessel *M*, the lower wall *P* of the passage *J* being apertured at *R* to facilitate this. The valve *N* is arranged to remain closed at steam temperature and to open below the arranged temperature. As the mixture of steam and air rises in the vessel *M* it strikes the upper end wall and the steam condenses. The air in the vessel *M* cools by radiation and the fall in temperature causes the valve *N* to open and allows the air to escape through the pipe *O*. Further steam entering and rising to the top of the vessel *M* then causes the valve *N* to close again, and so on. The condensate passes down the pipe *L* and mixes with feed water in the device and passes into the water space of the boiler. An adjustable stop valve *S* is provided in the pipe *L* intermediate with the boiler *F* and collecting vessel *M*. The term "air" is intended to include free air and other gases which may be present in the feed water, such, for example as carbon dioxide and dissolved oxygen as shown.—*July* 27, 1955.

733,713. March 2, 1953.—FORKED TUBE FITTINGS, Babcock and Wilcox, Ltd., Babcock House, Farringdon Street, London, E.C.4.

The invention relates to forked tube fittings suitable for use in bifurcated steam generator tubes. From the drawing it will be seen that a forked tube fitting



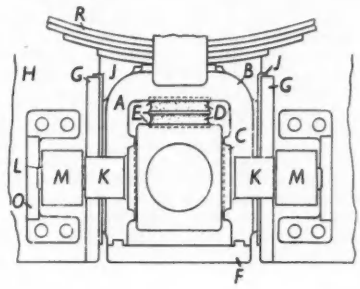
No. 733,713

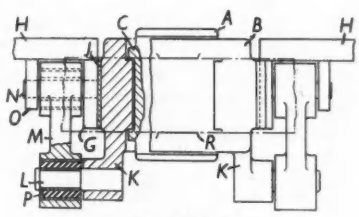
A is formed with bifurcations *B* and is welded to a main tube *C* and to branch tubes *D*, a weld seam *E* being formed in a groove between the bevelled edge of the main aperture *F* of the fitting and the end of the tube *C*, weld seams *G* being formed in grooves formed respectively between the bevelled ends of the cylindrical outer end portions of the bifurcations *B* and the abutting ends of the tubes *D*. The bifurcations *B* are linear and only of sufficient length to allow formation of and access to weld seams *G*. As shown, at least the inner end portions of the bifurcations converge towards the main aperture *F*, and the tube fitting consists of two identical parts which may be forged in the same die, which lie on opposite sides of a plane containing the respective axes *J* and *H* of the bifurcations and which are welded together at the opposing edges. Each of the pairs of tubes *D* include main parts in contact with one another and end parts of reduced diameter, there being sufficient space between the respective bifurcations at the ends to permit the deposition of the weld metal at the adjacent parts of the weld seam *G*. The specification also shows two further modified examples of fork tube fittings.—*July* 20, 1955.

RAILWAY ENGINEERING

734,354. September 19, 1952.—AXLE-BOX ASSEMBLIES, The English Electric Company, Ltd., of Queen's House, 28, Kingsway, London, W.C.2. (*Inventor: Eric Alton Binney.*)

Referring to the drawing, the vehicle axle is journalled in an axle-box *A* which is itself slidably mounted in an open-ended cage *B*. The axle-box is restrained by means of horn guides *C* so as to be movable relative to the cage in the vertical direction only, and a resilient unit, consisting of two rubber pads *D* bonded to metal plates *E*, is located between the upper face of the axle-box and the opposing face of the cage. The cage *B*, which is closed by a removable bridge piece *F*, is slidably mounted between





No. 734,354

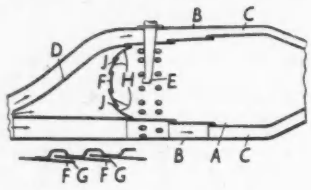
vertical guide plates *G* attached to the bogie frame *H*, removable rubbing plates *J* being interposed between the opposing faces of the cage and the guide plates. Two forwardly projecting lugs *K*, formed integral with the cage, carry pivot pins *L* which are coupled by links *M* to pivot pins *N* which extend between support brackets *O*, secured to the bogie frame, and the corresponding guide plates *G*. A resilient rubber bush *P* is fitted to each pivot pin. The main spring assembly *R* bears on top of the cage *B*. It will be apparent that a relatively small degree of resilience in the vertical direction is provided between the axle-box *A* and the cage *B* which allows low amplitude vertical movements to be absorbed locally, whilst larger amplitude vertical movements are taken up by relative movement of the cage *A* and the bogie frame. It will also be seen that the links *M*, whilst allowing relative vertical movement of the cage and the bogie, will resiliently restrain relative transverse movement of these two members. An alternative design is also shown in the specification.—*July* 27, 1955.

GAS TURBINES

733,485. May 16, 1952.—COMBUSTION CHAMBERS FOR PRIME MOVERS, Joseph Lucas (Industries), Ltd., Great King Street, Birmingham, 19. (*Inventors: Squire Ronald Jackson and John Stanley Clarke.*)

The invention relates to combustion chambers for jet-propulsion engines, gas turbines or other prime movers, and has for its object to provide a construction whereby deposition of solid carbonaceous matter on the end portion adjacent to the burners can be minimised or obviated. The drawing illustrates part of an annular combustion chamber *A* for a jet engine, or gas turbine. It is constructed from metal sheets, and is enclosed at its outer and inner peripheries by walls *B* forming with the adjacent walls of the combustion chamber the air jackets *C* to which air is supplied from a blower. The end of the combustion chamber adjacent to the entrance to the air jackets is rounded, and on this end, which, though designed for the admission of air, may be described as the closed end, is formed with or has secured to it a hollow annular nose piece *D* shaped to direct the incoming air into the outer and inner air jackets and

also together from the incoming air a stream required to be directed into the combustion chamber. Liquid fuel burners *E* contained in the combustion chamber are situated at convenient distances apart adjacent to, and adapted to direct the fuel towards, the closed end. In applying the invention to such a combustion chamber in the manner illustrated in the drawing, the central zone of the closed end is constructed from an annular arrangement of overlapping metal plates *F* arranged to form between them passages *G* through which air can flow to the combustion chamber from the



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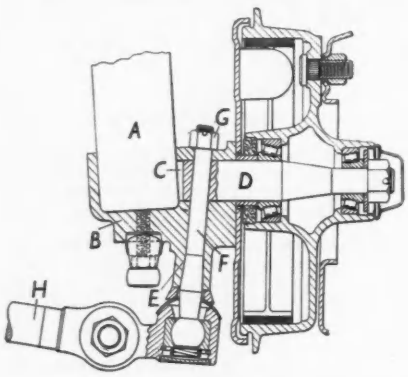
interior of the nose piece *D*. The rear edges of the plates are attached by spot welding or otherwise to corrugated edge portions of adjacent rings, which form other parts of the end walls. As shown, the other parts of the end walls are constructed from overlapping sheet metal rings *H* to provide between them air gaps *J* through which thin air streams can flow and sweep over the inner surfaces of the rings. The air streamlets emerging from between the ends and sides of the plates *F* sweep over the exposed parts of the inner surfaces of the plates and effectively prevent deposition thereon of carbonaceous matter resulting from incomplete combustion of the fuel. A modified design of combustion chamber is also shown in the specification.—*July* 13, 1955.

ROAD TRANSPORT

733,801. October 22, 1952.—Wheel Mountings for Motor Vehicles, Ford Motor Company, Ltd., 88, Regent Street, London, W.1. (*Inventor : Eric Olle Schjolin.*)

The invention consists of a wheel suspension having a generally vertical spring-loaded telescopic hydraulic shock absorber in which a stub axle for the wheel fits in the lower end mounting and is secured



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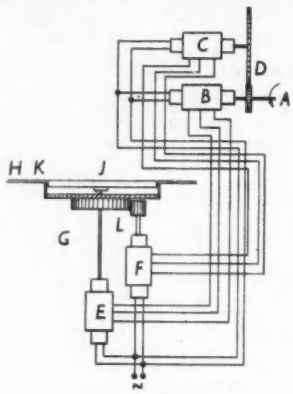
against outboard movement by means of a pin passing through a hole in the mounting and through the stub axle. *A* indicates the lower end of a hydraulic spring-loaded telescopic shock absorber, the upper end of which is mounted for pivotal movement about any horizontal axis extending through the upper end. An integral bracket *B* at the lower end is drilled with an aperture *C* into which fits the stub axle *D*. The bracket *B* is also formed with an aperture *E* to receive a pin *F*. When the stub axle *D* is in position a drill may be inserted down the aperture *E* and the stub axle drilled through. The pin *F* is then inserted and secured by a nut *G* at its top end. The lower end of the pin is formed as a ball which fits into a socket in the end of a radius arm *H*, which is pivotally secured at its inner end to the vehicle chassis frame (not shown). Various modifications may be made within the scope of the invention.—*July* 20, 1955.

MINING ENGINEERING

733,524. June 22, 1953.—Position Indicators for Mine and like Hoists, The British Thomson-Houston Company, Ltd., Crown House, Aldwych, London, W.C.2. (*Inventor : Geoffrey Edmund Woodliff.*)

The invention relates to indicators suitable for mine winding gear and like hoists where the position of the cage is not evident to the hoist operator and it is necessary to give the operator a visual indication of the position. In the drawing, the drive for the indicator is to shaft *A*, which is associated in any suitable manner with the hoist drums. The shaft drives transmitter Selsyn *B* directly and Selsyn *C*



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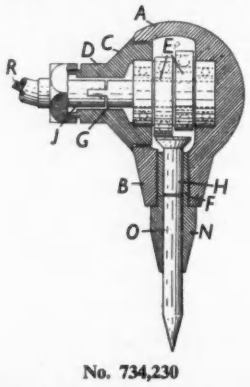
through reduction gearing. The Selsyn transmitters are connected electrically with corresponding receivers *E* and *F* in the indicator unit *G*, which is mounted remotely to the hoist drum. The indicator has three indicating members *H*, *J* and *K*, of which *H* is fixed and can be scaled so that a full wind corresponds to less than 360 deg. Indicating member *J* is driven from the shaft *A* through the intermediary of Selsyns *B* and *E*, so that it rotates at a speed corresponding to that of the drum shaft, one revolution corresponding to one drum turn. Indicating member *K* can be provided with a scale or pointer so that its angle of rotation for a full wind corresponds to the full-scale reading provided on the outer indicating member *H*. Indicating member *J* thus performs several revolutions for a complete travel of the cage. Indicating member *K*, however, performs, for a full wind, a part of a revolution corresponding to the scale on the indicating member *H*, and is provided with a scale or index finger to co-operate with that member. To this end, indicating member *K* is driven through the intermediary of Selsyns *C* and *F* and gearing *D* and *L*. To position the cage accurately at the ends of the wind, the indications on members *H*, *J* and *K* are made to coincide at their respective locations, the movement of the index mark on member *K* indicating the travel of the conveyance and its approach to the predetermined level, while the movement of the index mark of member *J* shows when the conveyance is accurately located at the level. —*July* 13, 1955.

WORKSHOP TOOLS AND APPLIANCES

734,230. April 13, 1953.—Mechanical Chipping Hammers, Flexible Drive and Tool Company, Ltd., Queensberry Way, London, S.W.7. (*Inventor : Peter George Pasqua.*)

The invention relates to mechanical chipping hammers or tools used by masons, or for scale chipping purposes, particularly in positions not readily accessible for hand operations. As shown in the drawing, a thick metal casing *A* is made of approximately hemispherical form, open at one side and

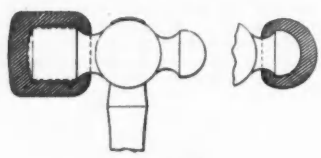


No. 734,230

having a conical boss *B* at the bottom. The open side is internally threaded, to receive a closing cap *C* with a central boss *D*. A shaft *G* rotates on ball bearings and is formed with two eccentrics *E*, arranged side by side at 180 deg. to each other and carrying ball races. A ring freely surrounds each eccentric ball race or cage. The bottom boss is bored and screwed to receive a bush *F*, which is bored to receive a pin *H*, having a head for engagement with the two outer eccentric rings. The bush has a conical extension and the stem or haft of a chipping tool is pushed into the extension so that it engages the outer end of the pin. The end of the shaft which extends into the boss of the closing gap *C* of the casing forms a driving arrangement with the adaptor *J*, and the driving end of the flexible shaft, which is driven by an electric motor. When the eccentrics are rapidly rotated the eccentric mounting of the rings relative to the shaft axis sets up an intense vibration which is transmitted to the chipping tool by the pin. The practically spherical casing, and the lower boss on it, constitute a convenient hand grip, but if desired other shapes may be adopted for the casing.—*July* 27, 1955.

733,391. May 5, 1953.—Hammer Head Attachment, William Emery Martin, Kewanee, Illinois, U.S.A.

The invention relates to an auxiliary hammer head in the form of an attachment for the conventional type of hammer. It consists generally of an auxiliary striking cap which can be slipped over the head of a hammer to provide additional means for carrying out



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metal working operations which cannot be accomplished with a hard-headed hammer, and provides a striking material of a different hardness than the normal material of the hammer head. The arrangement of such a hammer head can be seen from the accompanying drawing.—*July* 13, 1955.

Catalogues and Brochures

Soag Machine Tools, Ltd., Juxon Street, Lambeth, London, S.E.11.—Illustrated stock list.

Briggman Brothers, Ltd., Holderness Engineering Works, Hull.—Illustrated publication giving full technical details of the new "Tiger V" excavator.

British Resin Products, Ltd., Devonshire House, Piccadilly, London, W.1.—Publication describing the complete range of "Cellobond" foundry resins.

Abingdon King Dick, Ltd., Abingdon Works, King's Road, Tyseley, Birmingham, 11.—Illustrated catalogue covering the complete range of "King Dick" hand tools.

B.E.N. Patents, Ltd., High Wycombe, Bucks.—Catalogue No. CB.120, giving details of a variety of tools for drilling, scaling, scraping, chipping, cutting sheet metal, die grinding and similar duties.

English Electric Company, Ltd., Stafford.—Relay manual, giving brief details of the complete range of protective and auxiliary relays and the basic induction disc, induction cup and hinged armature units employed.

Hackbridge and Hewittic Electric Company, Ltd., Walton-on-Thames, Surrey.—Publication No. R.190, describing Hewittic mercury arc rectifiers. Training leaflet No. T2, giving an outline of the company's engineering training scheme for students.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

Wed., Aug. 31st., to Wed., Sept. 7th.—Annual Meeting in Bristol.

BRITISH INSTITUTION OF RADIO ENGINEERS

Wed., Sept. 28th.—London Section : School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, "Extending the Limits of Resistance Measurement Using Electronic Techniques," G. I. Hitchcox, 6.30 p.m.

ELECTRIC RAILWAY SOCIETY

Sat., Sept. 3rd.—Visit to Stonebridge Park Power Station and Overhaul Works, 1.40 p.m. (Stonebridge Park Station).

ENGINEERING, MARINE AND WELDING EXHIBITION AND THE FOUNDRY TRADES EXHIBITION

Thurs., Sept. 1st., to Thurs., Sept. 15th.—Olympia, London. Open each weekday from 10 a.m. to 8 p.m.

INCORPORATED PLANT ENGINEERS

Tues., Sept. 6th.—London Branch : Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2, Further discussion on the 1955 conference paper, "Is There a Future for Tracked Earth-Moving Plant in View of the Development in Rubber-Tyred Earth-Moving Plant ?" 7 p.m.—Edinburgh Branch : 25, Charlotte Square, Edinburgh, Members' Evening, 7 p.m.

Wed., Sept. 7th.—Leicester Branch : College of Art and Technology, The Newarkes, Leicester, "Underwater Television," 6.30 p.m.

Thurs., Sept. 8th.—Glasgow Branch : Scottish Building Centre, 425/427, Sauchiehall Street, Glasgow, "Developments in Machine Tools," J. R. Young, 7 p.m.

INSTITUTE OF WELDING

Wed., Nov. 2nd., to Fri., Nov. 4th.—Autumn Meeting, London.